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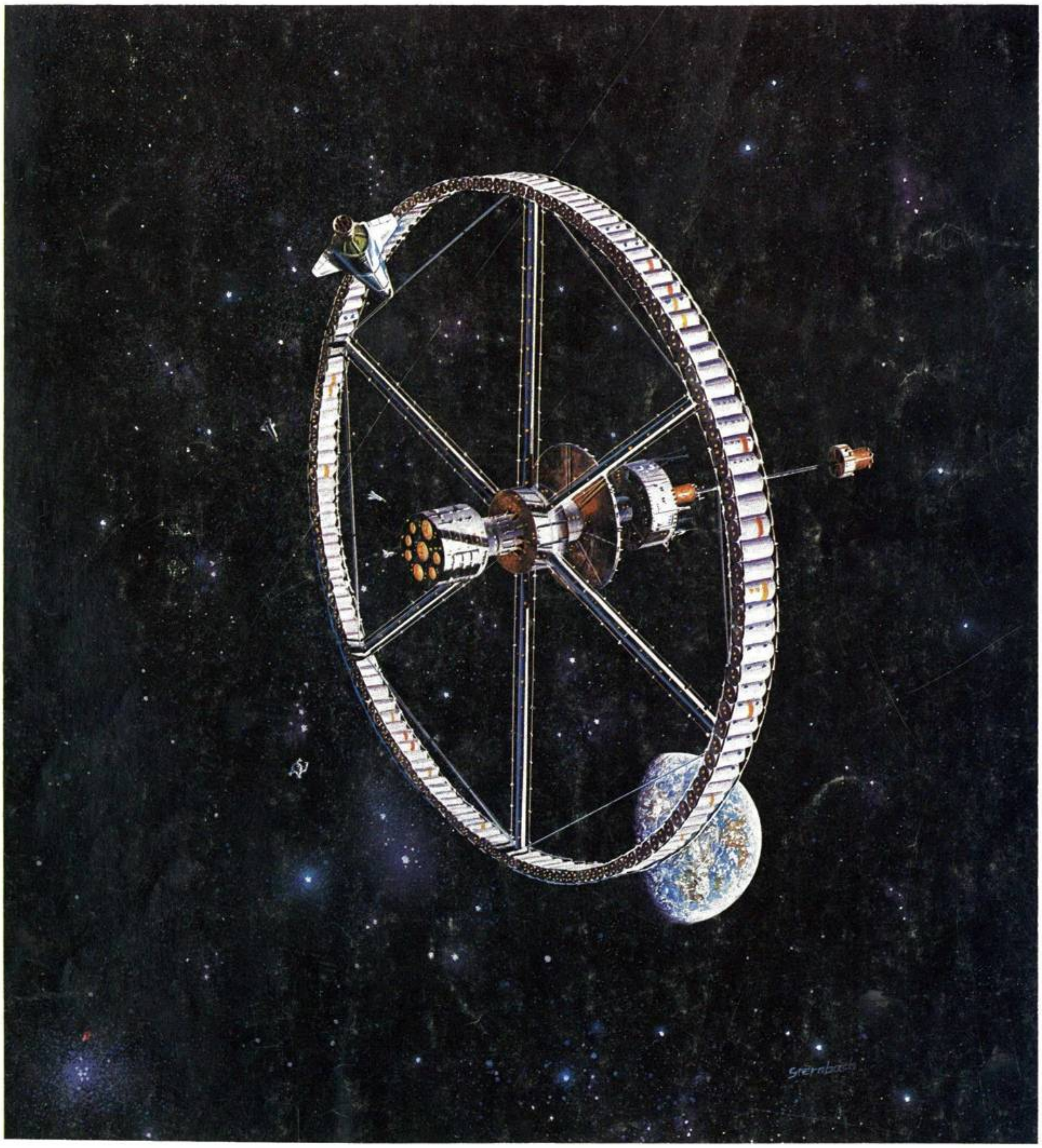

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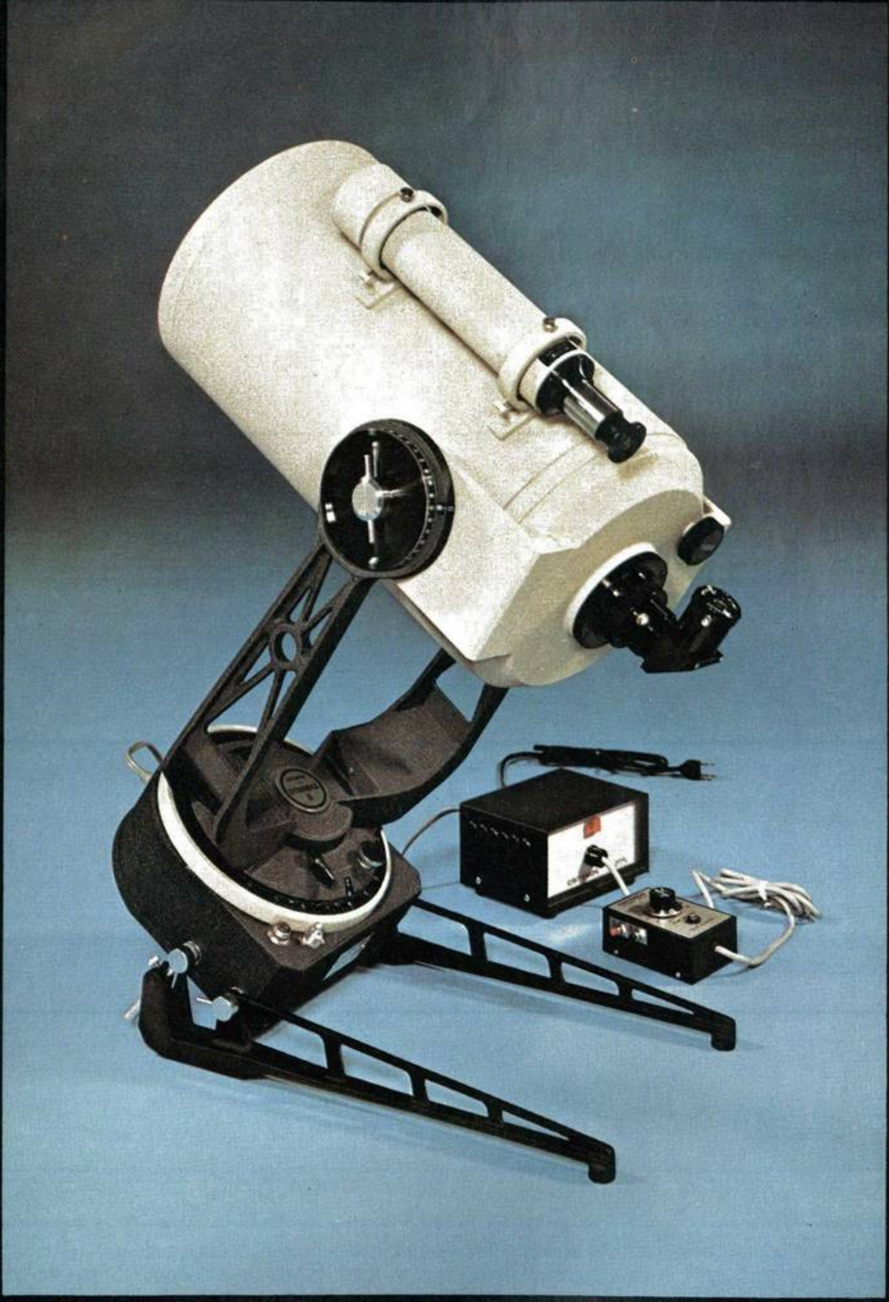

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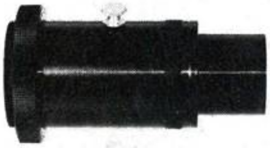

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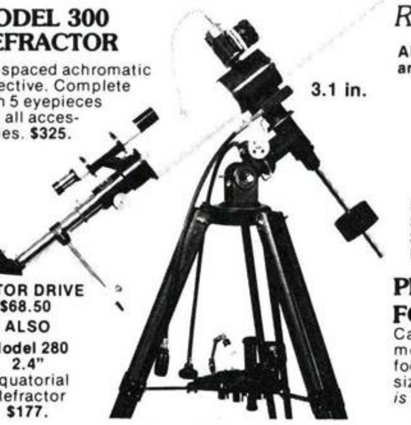

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January 1976 Vol. 4, No. 1

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Cover

Wheeling slowly above the gibbous Earth, this mile wide space station is the home for 10,000 colonists. The tiny shuttle rockets (actually the size of jetliners) near the station's hub are bringing ore from the lunar surface to be refined in the station's zero gravity manufacturing center. Artwork by Rick Sternbach.

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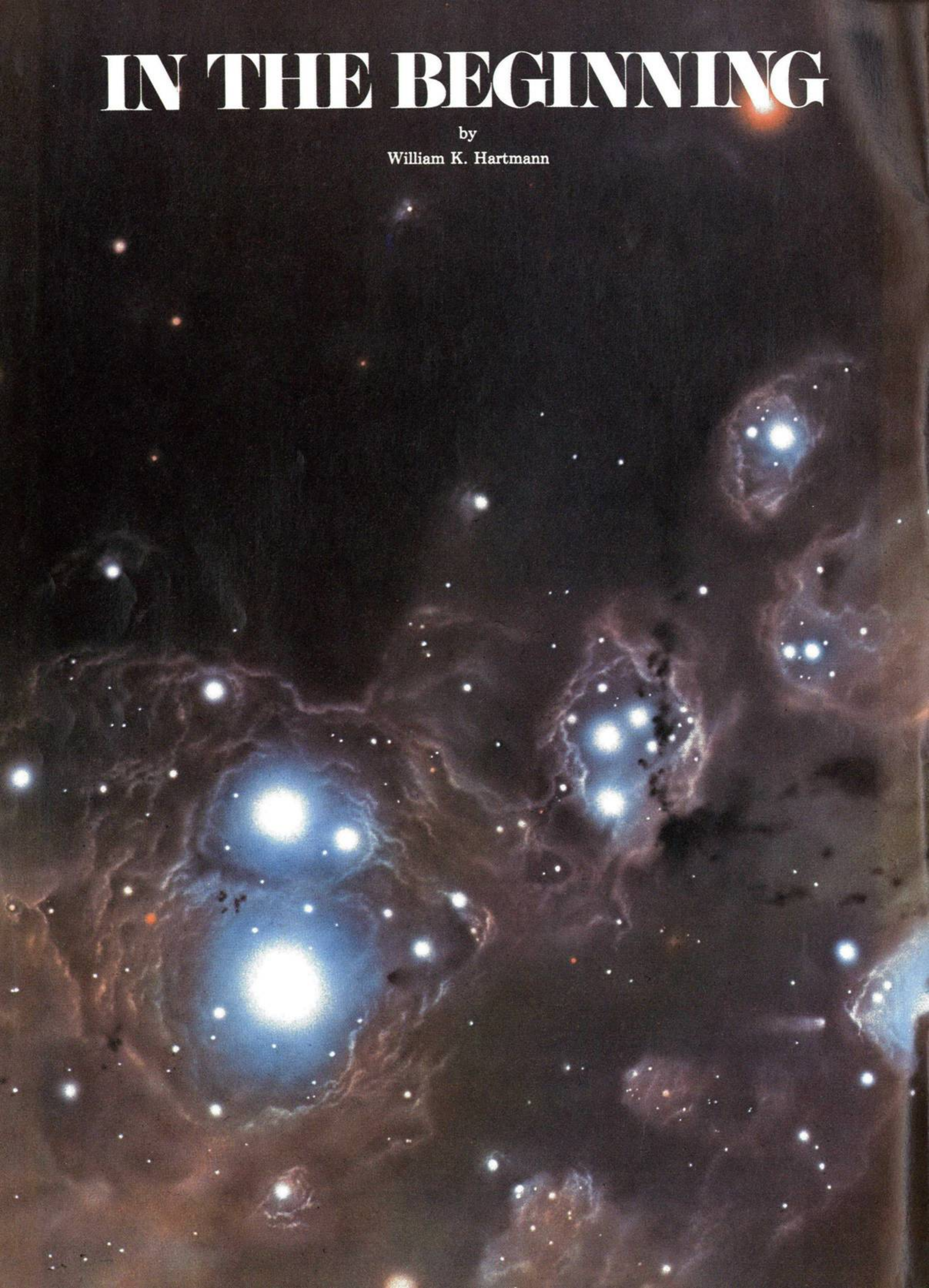
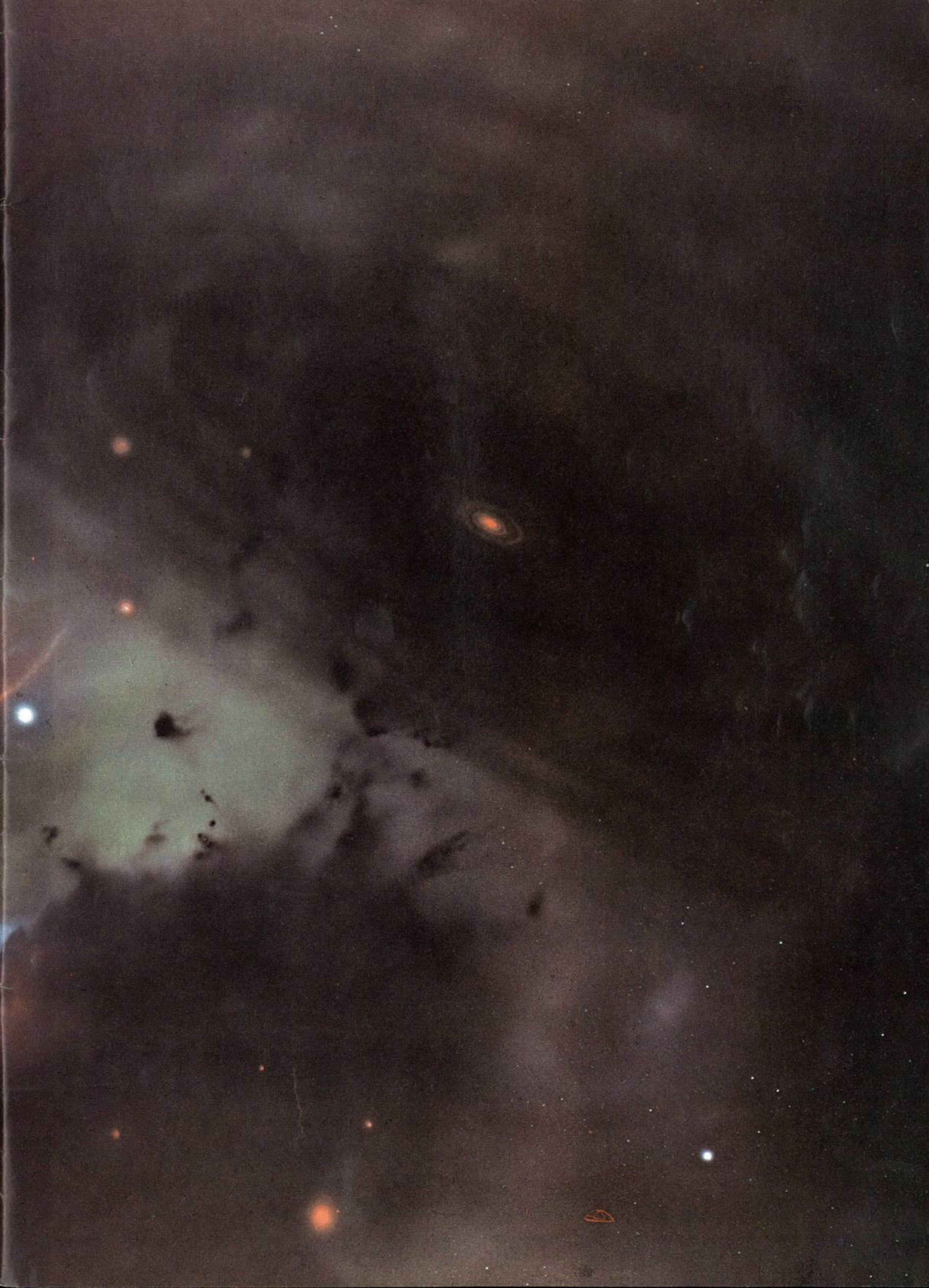
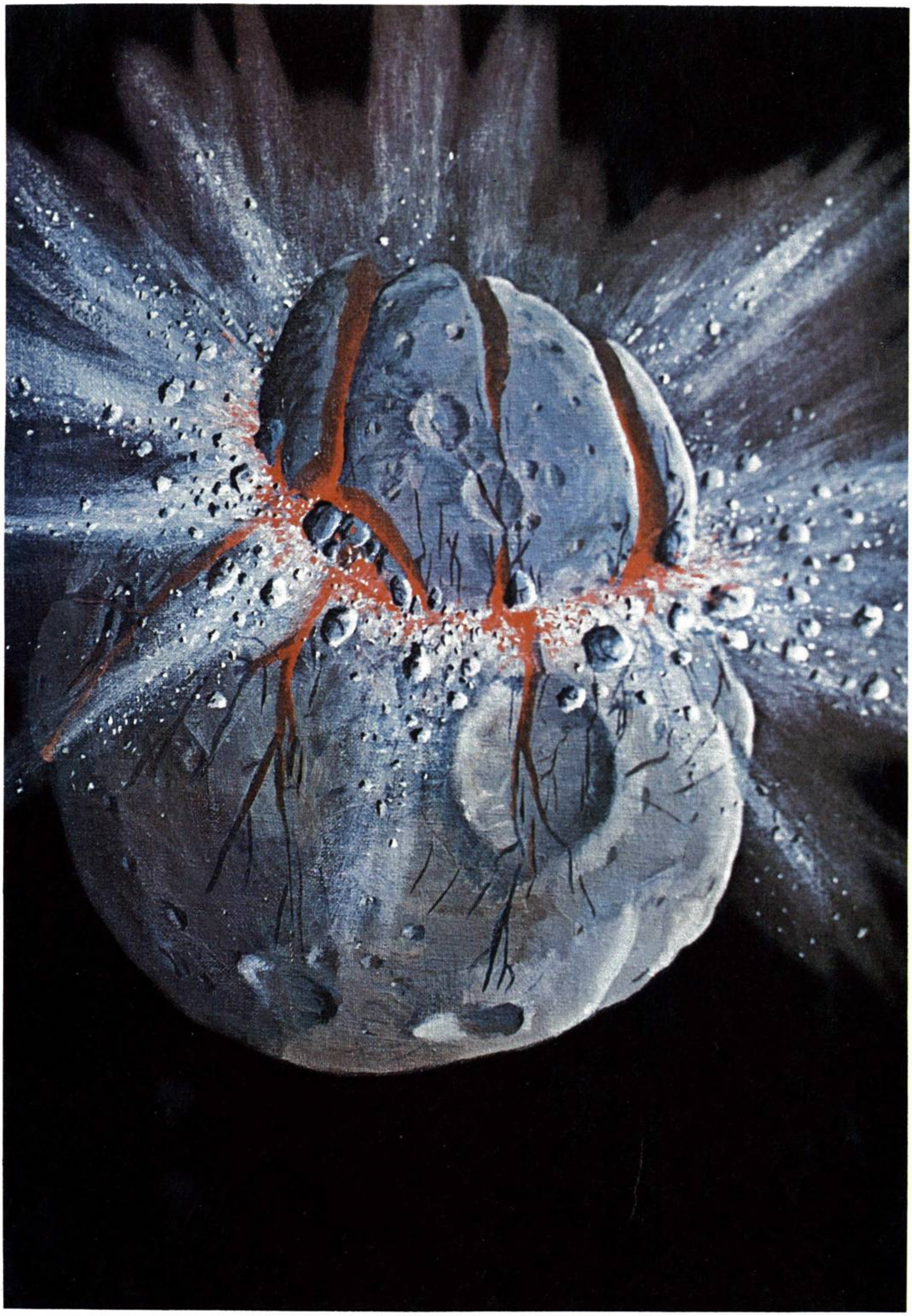
IN THE BEGINNING

by

William K. Hartmann







The solar system chef, in formulating a recipe for creation of our sun, planets and satellites, had to be an eclectic scientist. To build the world we know, he had to delve into many disciplines, because the ingredients were not available in one, narrow cupboard.

It has taken the same scientific eclecticism for man to start unraveling the mystery of our solar system's creation. Until recently, only astronomers were involved in this kind of research, and scientific tunnel vision may have inhibited the initiation of celestial research in other fields. Now, however, chemists, physicists, geologists and others are making contributions, and the resultant progress is remarkable.

How this narrow view developed is easy to understand. We have a tendency to cut off Earth from the universe, and that blinds us in our daily routines. But, pause for a moment... let some sand trickle through your fingers...pick up a rock. These are cosmic materials — solid cosmic silicate particles! After all, Earth is just a giant rock, so we are walking on cosmic material every day. Ultimately, it is material that must have been formed in some astronomical kitchen.

It is our inability to make this connection that has seen the separate development of the disciplines of geology and astronomy. But when the geologist asks where this rock came from — what is the source of the material in the rock — it is then that he realizes he must broaden his scientific perspective.

Certainly, he is aware that the isotopic composition of the rock could be analyzed to determine the rock's age. That, however, is simply an interesting diversion. It tells us when the rock formed from something else, but not where the something else came from. The astronomer is asking the geologist a very basic question: If the rock hardened from lava 10,000,000 years ago, where did the lava come from? Or, what was the original source of the matter now in rocks and oceans and trees?

The answer has proved elusive. We have searched Earth for older and older rocks that might offer a clue, and some areas have revealed some fairly ancient rocks. For instance, the so-called Canadian shield surrounding Hudson Bay yields rocks that are typically a billion years old — with some as old as three billion years!

Caption for pages 6 & 7

The solar nebula spins in a cloud of obscuring dust on the right side of this rendition. In the background, many light-years distant, we see other such dark clouds as small dots silhouetted against an Orion type nebula. Painting by Adolf Schaller.

Two planetesimals collide at thousands of miles per hour, ejecting a spray of fragments. The larger body is about 30 miles in diameter. The force of the collision may be great enough to fracture one or both of the bodies into several intermediate sized planetesimals. Artwork by William Hartmann.

The further back in time we travel, the rarer are the samples. The oldest rocks found on Earth till now are about 3.7 billion years old. Unfortunately, the rock trail only leads us through an endless series of meltings and solidifications. No clues remain to indicate from what part of the pantry the original material came. The rare old rocks of Earth have been recycled so often that we have scant records of their origin.

So, even though we do not need to leave Earth to get samples of cosmic materials, the materials that remain give few clues about the origins of Earth and the rest of the solar system. Earth's rocks are simply inadequate.

Lunar rocks are far better; most of these are older than three billion years. Rocks found in the younger regions of the moon crystallized from lava about 3.5 billion years ago. When returned by the first two Apollo landing crews, tests quickly confirmed predicted ages. Scientists immediately anticipated that later landings in the heavily cratered uplands would produce *genesis rocks* that had remained intact since the moon and planets formed.

Again, predictions were confirmed. Upland rocks were older. However, a cutoff date appeared that was not the date of planetary origin. The oldest upland rocks had reached their present state by cementing of igneous fragments about four billion years ago. Scarcely any rocks could be found that were more than 4.1 billion years old. Fortunately, additional isotopic dating investigation showed that much of the original crystalline material from which the rocks were assembled had formed 4.6 billion years ago.

This date is a sort of magic number in planetary studies, because it also represents the time during which most meteorites formed. While some reached their present state more recently, 4.6 billion years ago seems to be the earliest starting date for any meteorite.

Thus, a survey of all available solid material — terrestrial, lunar and meteoric — tells us that the ultimate cutoff date is 4.6 billion years ago. Many rocks are that old, but none are older. Something very significant happened in the solar system at that time, from which it is believed solid material originated.

So, we are right back where we started. We have a when, but not a what. Research continues in this area, and the prospects are very exciting for a number of reasons.

First, new information is being accumulated through space exploration and meteorite recovery programs.

Second, evolution of the solar system is a field of study wherein modern stellar and geochemical research converge. As stated earlier, these are no longer viewed as separate disciplines. Scientists who hardly had occasion to meet in the past are now frequently finding themselves engaged in debate on a common problem.

Third, it leads to the exciting prospect of discovering facts about the origin and evolution of other planets — planets that might be havens for alien life or that might harbor bands of people in future colonies.

While the origin of the solar system has long been a scientific puzzle, we are now in a better position to study it than any of our ancestors were. At the time of the Renaissance, scientists were unable to separate the origin of the solar system from that of the universe. Thus in 1644, Rene Descartes attributed Kepler's laws of orbital motion to the formation of stars and planets. He postulated that they formed out of rotation eddies in a universal primordial gas, with one large eddy making the sun and smaller eddies yielding the planets. This type of theory was called *evolutionary*, since it predicted planets as a normal outgrowth of star formation.

An alternative theory, presented in 1745, suggested that the planets formed from material blasted out of the sun by an accidental collision with a large, passing body. This theory was called *catastrophism*, and predicted planets would be only rare accidents.

Parallel lines of theorizing continued for several centuries. The dynamic picture of a rotating solar nebula was unassailable and appealing. However, it had one fatal flaw: If a spinning skater or dancer pulls in her arms, she spins faster. Similarly, if a rotating nebula shrank, it too would spin faster. Therefore, if it started with enough momentum to spin off the material to form planets, the core would be rotating very fast in a flattened form, constantly preparing to throw off still more mass. Instead, the sun rotates slowly — once in every 25 days — and is virtually spherical. It simply does not have enough spin to support the spin-off model.

For this reason, evolutionary theories had been nearly abandoned by the early years of this century, and catastrophist theories became quite fashionable. Probability of collisions between stars was too low, and such an event too rare to be very likely. However, theorist Fred Hoyle and others speculated that a supernova near our sun might have shot gas into the area and created the nebula that then evolved into planets. If it was a stellar collision or a nova that produced our planets 4.6 billion years ago, then we must assume that planets are quite rare in the universe.

Now, with a new avalanche of observations and theoretical advances beginning around 1950, the pendulum suddenly has swung back toward evolutionary theories that emerged from various disciplines.

Around 1950, scientists began pointing out that magnetic forces might have been more significant in the early solar system than were gravitational forces. The most interesting interaction was between the sun and the nebular gas immediately around it. According to one early theory, the sun would have been rotating rapidly. However, unknown to theorists at that time, the sun's magnetic field would have been rotating through surrounding ionized gases — causing an eventual rotational slowing drag. This slowing is similar to that experienced by a spinning ball lowered into water.

If indeed the sun's ancient magnetic field had been strong enough, then its present slow rotation was caused by the very same nebula that provided the material to form our planets.

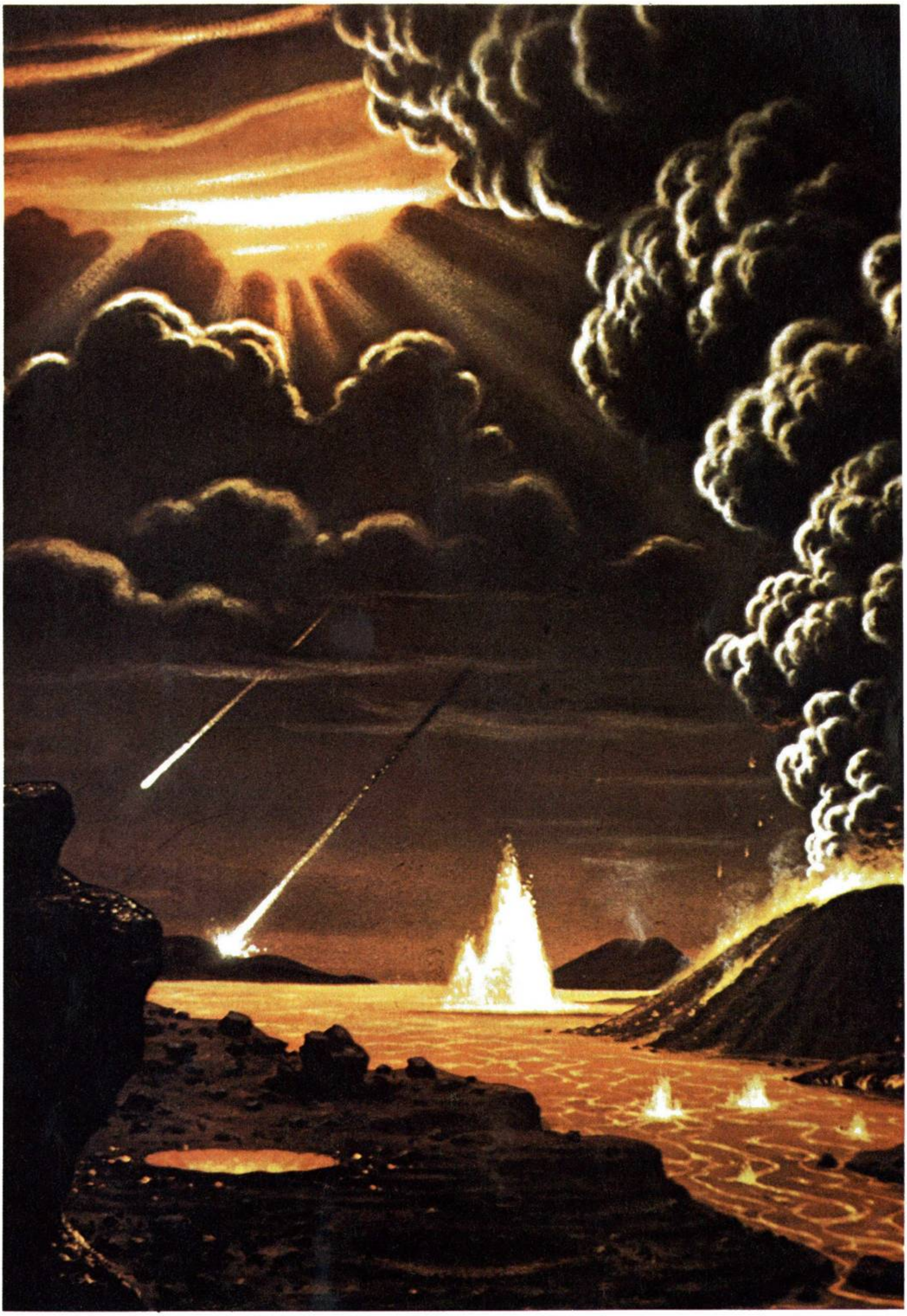
Meanwhile, observational astronomers found evidence that many stars — especially young stars — do have strong magnetic activity. These observations have also shown that very young stars are, in fact, spinning faster than they do when they reach their final, stable configuration. Thus, there is strong support for the thesis that stars form in a rapidly spinning state, but slow down quickly in their early years. This combination of magnetic principle and astronomical observation resurrected the evolutionary theory that our solar system planets formed from a disk shaped nebula.

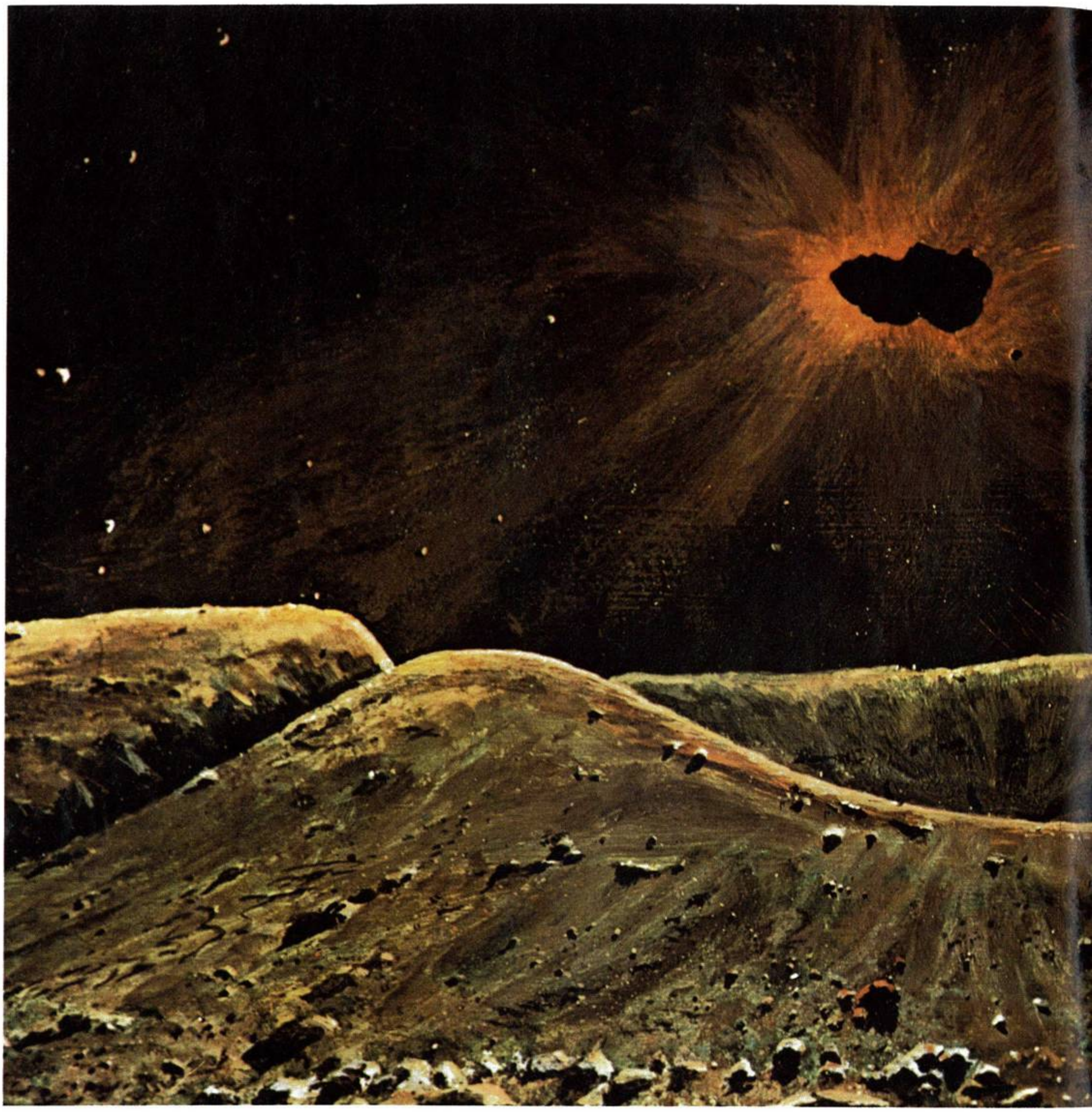
But what of the nebula itself? Is there any indication that such a nebula might actually accompany a newly formed star? This knowledge is essential, because only this kind of nebula could provide the medium from which planets could form. Astronomers began accumulating evidence to support this possibility in the 1960s, and T Tauri stars seemed to be the answer. These unstable stars seem to be newly formed, and observations indicate they may be shedding gas and dust that surrounded them during formation.

An even earlier stage of star formation is probably represented by certain infrared stars. These are stars that are invisible or only dimly visible to human eyes, but are bright in the infrared. According to the laws of radiation, their infrared flow indicates they contain dust grains at the relatively low temperature of just a few hundred degrees. These dust grains are responsible for blocking much of the visible light from the young star inside the nebula. Recently, spectral observers have identified absorption bands that indicate at least some of the dust grains in these nebulae are silicate (rocky type) materials.

Dusty nebulae enclosing young stars and containing grains of silicate material...this is beginning to sound like the recipe for making planets. Could we actually be viewing the conception of infant solar systems? It is very likely indeed!

In Earth's early history, the planet went through a period of accretional bombardment, gradually growing in size. Toward the end of this process, Earth was still "sweeping up" smaller bodies which shrieked through its poisonous atmosphere to impact on the lava-flooded surface. Artwork by David Hardy.





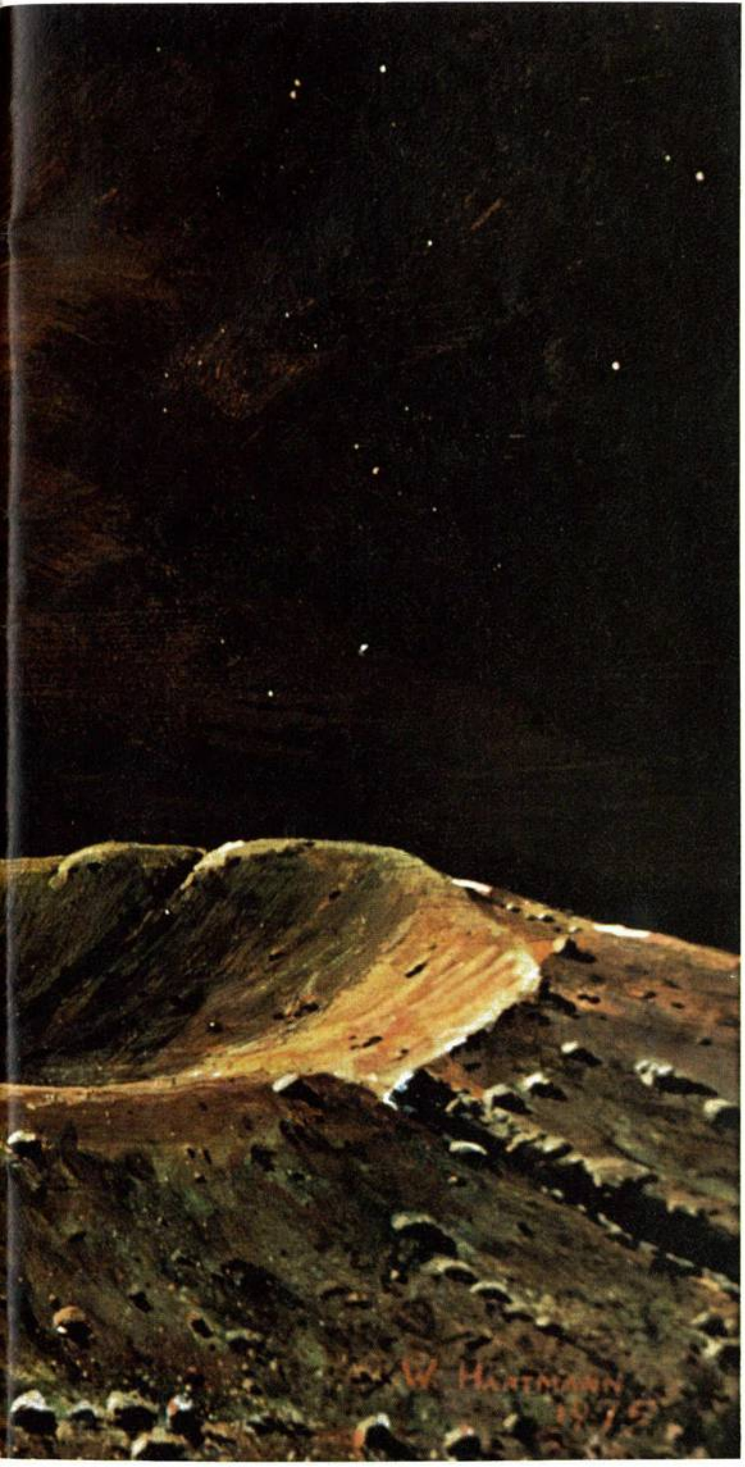
In the swarm of mile sized planetesimals that surrounded the sun before full-fledged planets formed, collisions and near-misses must have been common. In this artist's impression of one such near-miss, a passing planetesimal causes a momentary eclipse, blotting out the sun's light to reveal its corona — larger and more active than it is now. Intervening dust reddens the corona's light. Artwork by William K. Hartmann.

These nebula/new star combinations — called *cocoon nebulae* — are wrapped in an opaque nebular cloud of dust as they form. But as the dust particles accumulate into a few larger planetary objects, starlight can penetrate through the nebula — and the star appears, as if newly born.

But the question remains: What exactly does happen in such a cocoon nebula? Specifically, what happened in our solar cocoon nebula 4.6 billion years ago to produce planets? And where do those first grains of dust come from?

Surprisingly, the answers to these questions — at least to the extent that we do have answers — have not been provided by astronomers, but instead by chemists.

One explanation was that certain mineral features of meteorites — such as bound water — could not have been formed at temperatures greater than a few hundred degrees Fahrenheit. This theory ruled out previous models that had meteorites (and other



planetary matter) forming from molten blobs of magma, hot as a seething volcano.

For instance, the type of meteorite we call a carbonaceous chondrite has significant amounts of bound water which would have boiled away if the rock had ever been strongly heated. So, matter that formed it must have been cold when it came together — and it stayed cold for 4.6 billion years.

This theory was like a seed that fell into fertile soil. For nearly 20 years there was a slow growth of thought based on this kernel of inspiration. Then, in the late 1960s and early 1970s, there was a profuse harvest.

A younger generation of physical chemists took the basic theory and applied it to the astronomical and meteoric evidence that had accumulated during the previous 20 years. And it strongly indicated that a hot gaseous nebula, composed of solarlike material, existed in the solar system shortly after the sun formed 4.6 billion years ago. It surrounded the newly formed sun in the shape of a disk, with the greatest density confined to the ecliptic plane.

According to one model, the nebula was cooling from an initial temperature of more than 3,000 degrees Fahrenheit. At this point, a number of chemists asked themselves this simple question: What will happen in a cooling solar gas containing mostly hydrogen and helium, with impurities such as iron, silicon and oxygen?

We get a clue from our own atmosphere. If a cloud of air is cooled, particles in the shape of snowflakes, raindrops or hailstones form. The same thing probably happened in our cooling nebula. Solid particles appeared in a sequence as the solar cloud cooled.

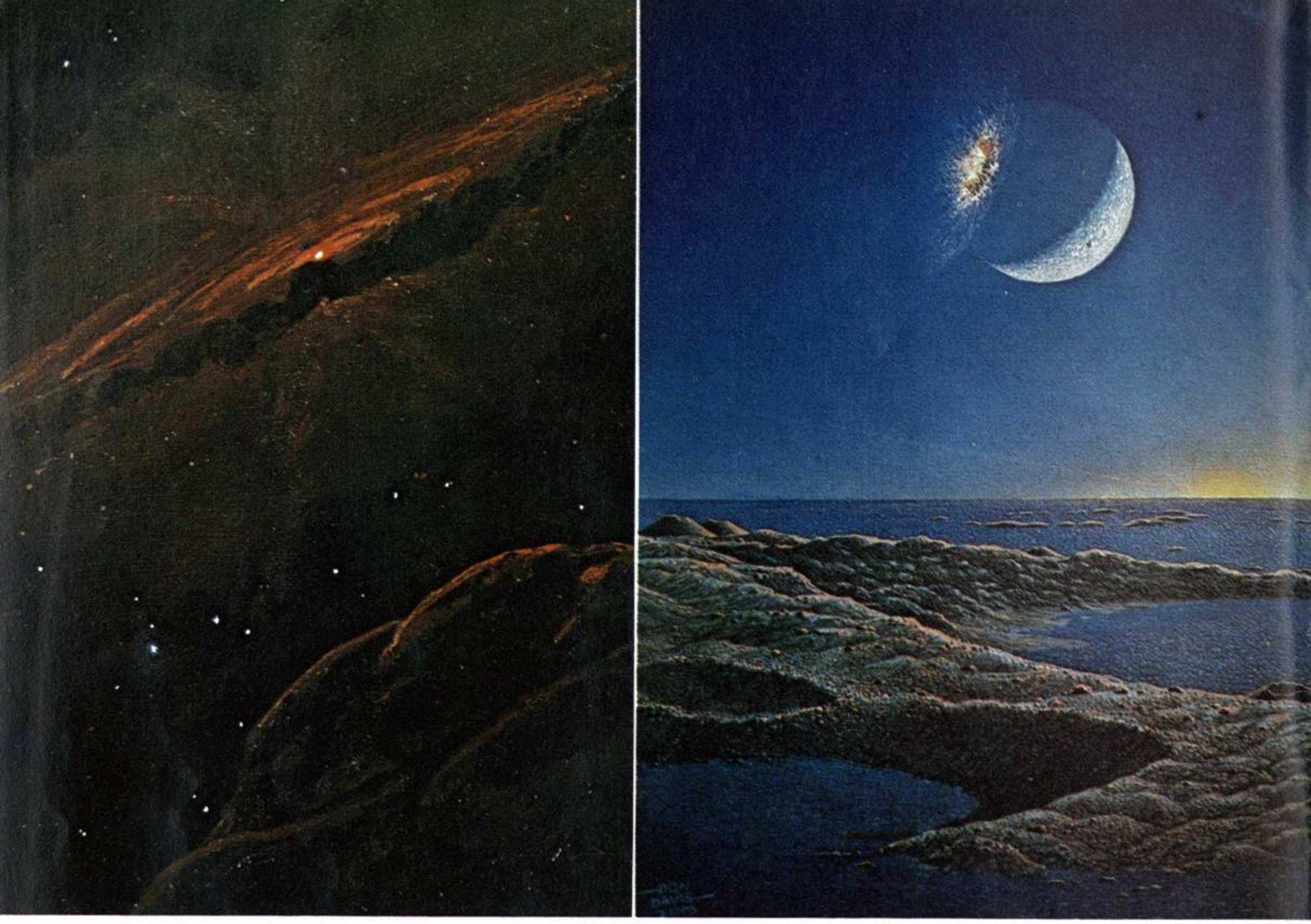
Sequentially, at about 2,400 degrees Fahrenheit, microscopic grains of oxides of elements such as aluminum, titanium and calcium appeared. Nickel iron grains condensed by the time the temperature dropped to about 2,050 degrees. After further cooling to around 1,900 degrees, a still more important and abundant precipitate began to condense in the form of silicate and ferrosilicate mineral grains. These include enstatite, pyroxene and olivine. Finally, after a longer interval, the temperature in the outer nebula reached about 32 degrees Fahrenheit, and ices began to form. The abundant hydrogen combined to make crystals of water, methane and ammonia.

Obviously, these experimental results advance our understanding greatly. They explain certain meteorite minerals, and are consistent with the discovery of silicate grains in nebulae believed to surround other young stars.

Unfortunately, the exact history and destiny of the particles is not yet clear. It depends partly on the actual rate of cooling. Some analysts believe that the nebula cooled to the point where silicates appeared in just a few thousand years. If the nebula cooled that fast, then particles would have had no chance to interact, and the result would be a combination of gases and all the different types of microscopic dust and ice grains.

On the other hand, if the cooling was slow, the first types of grains might have accumulated in clumps before the next mineral condensed. One can imagine that iron grains might have collided and welded into large masses of iron before any silicates appeared. Could these be the forerunners of our nickel-iron meteorites? Perhaps.

Some analysts have gone even further, suggesting that the entire iron cores of Earth and other



These pictures show two stages in the evolution of a planet. At left, a little sunlight filters through the dense cloud of dust and rock that will eventually become our planetary system. On the right, 3.9 billion years ago, there were no spectators to this dramatic example of accretion — a large planetoid crashing into the moon. The scar from this impact is still visible as the walled plain Mare Imbrium, more than 1/4 as wide as the moon itself. The moon was much closer to Earth then, and tidal friction had not yet slowed its rotation to make one side always face Earth. Left: Artwork by William K. Hartmann. Right: Artwork by Don Davis.

planets might have accumulated in the same way. They envision the planets building in onion-skin layers. Iron cores form first. Silicate mantles are added. Then, ice frosts their surfaces, melting and vaporizing to form oceans and atmospheres.

However, many geochemists object to this concept — favoring instead the more traditional view that Earth accumulated as a more or less homogeneous ball of iron silicate which melted. This allowed molten iron to drain to the center, while silicate slag rose to the surface to produce mantle and crust.

Compromise views are also possible. For instance, the early grains of iron or nickel-iron alloy may have served as condensation nuclei for silicate materials, just as dust grains serve as condensation nuclei for raindrops in our own atmosphere.

In that case, the nebula could have been filled with micron sized dust grains composed of iron cores and silicate mantles, perhaps in different proportions in various parts of the nebula. Such grains are very similar to those now hypothesized in the cocoon nebula that is believed to surround protostars.

In fact, one recent study concludes that a mixture of silicate grains could produce the spectral features observed in such objects. Another showed that silicate minerals condensed from beams of atoms such as silicon, magnesium, iron and oxygen. This supports both meteoric analyses and the interpretation of stellar observation.

Such work illustrates how chemical, meteoric and astrophysical studies are converging to unveil the processes that occurred during the solar system's early years. Scientists are making the exciting discovery that they are all working in the same kitchen, and that their cooperative efforts can produce dramatic revelations.

Those who have accepted the picture sketched so far face one more major question. That is, how did the microscopic grains grow to have diameters of tens, hundreds or thousands of miles?

One possible answer is *accretion*. This refers to the sticking together of particles when they collide. The simple dynamics of a gaseous nebula assure that collisions between grains at a wide range of speeds is inevitable.

For example, suppose a target body gets hit by a particle having a mass of one ounce. If 100 ounces of the target are shattered and blasted away into space, the target will obviously grow smaller. If, instead, the particle penetrates into the target without blasting away much material, then the target gains mass. If the latter process happens many times, the target particle would grow from a small dust grain to an appreciable pebble. Such pebbles, ranging from a few inches to a few miles in diameter, are usually called *planetesimals.*

Some investigators have assumed that the process of accretion alone caused the dust grains to accumulate into planetesimals, filling the solar system with asteroidlike bodies. There is even some direct evidence of this happening. A recent report tells of a meteorite in which a very tiny grain of magnetite had embedded itself in a not-much-larger meteoric particle, apparently the result of a collision. The discovery made by microscopic study of the meteorite offers substantial evidence that collisions can be responsible for the accumulation of mass in meteorites.

The primary difficulty in postulating the evolution of planets through this process is difficult primarily because the growth of brick sized bodies by collision seems unlikely. We are discussing velocities equal to those of bullets, and bullets fired into rocks shatter both the bullet and the rock. In other words, bare, rocky planetesimals would lose mass during collisions, and would not have enough gravity to retain the pieces. There is a great hurdle to overcome in getting planetesimals to grow to a point where gravity begins to help retrieve impact-freed fragments.

One possible explanation is that planetesimals become covered with a fairly deep layer of dust. Then, small projectiles could bury themselves in the dust without causing any fragments to fly away. Snow or ice could have the same effect.

Another solution has been advanced. In this model, the original dust grain condensates would tend to settle toward the plane of the solar system, collecting in a layer near the ecliptic. Here they would be much more concentrated than in the thicker nebular disk where they formed, and their gravitational interactions would thus be stronger. Local disturbances, such as turbulent eddies in the gas, would form higher concentrations of particles to serve as gravitational centers for surrounding particles. In this way, grain aggregates as large as 100 yards across would form, probably as fast as the condensates appeared. These planetesimals themselves would have similar interactions, and in a few thousand years a second generation of larger planetesimals could form.

This theory gets us past the growth hurdle, because it is much easier to picture the continued growth of asteroidlike objects that are a few miles across. For example, they might easily acquire a layer of dust grains that would help capture additional particles. Further growth would be merely a consequence of the rate of collisions between particles. A continued growth rate of several inches a year is possible under these conditions. This would produce a moon sized body in only 10,000,000 years — only a blink of time to the cosmic eye.

Growth did not occur smoothly, however. Meteoric evidence tells us that destructive collisions occurred among larger objects in the formative years of the solar system. Stony iron meteorites, for instance, were once molten material inside planetesimals more than 100 miles wide. It appears they were set free when their parent body was shattered in a major collision.

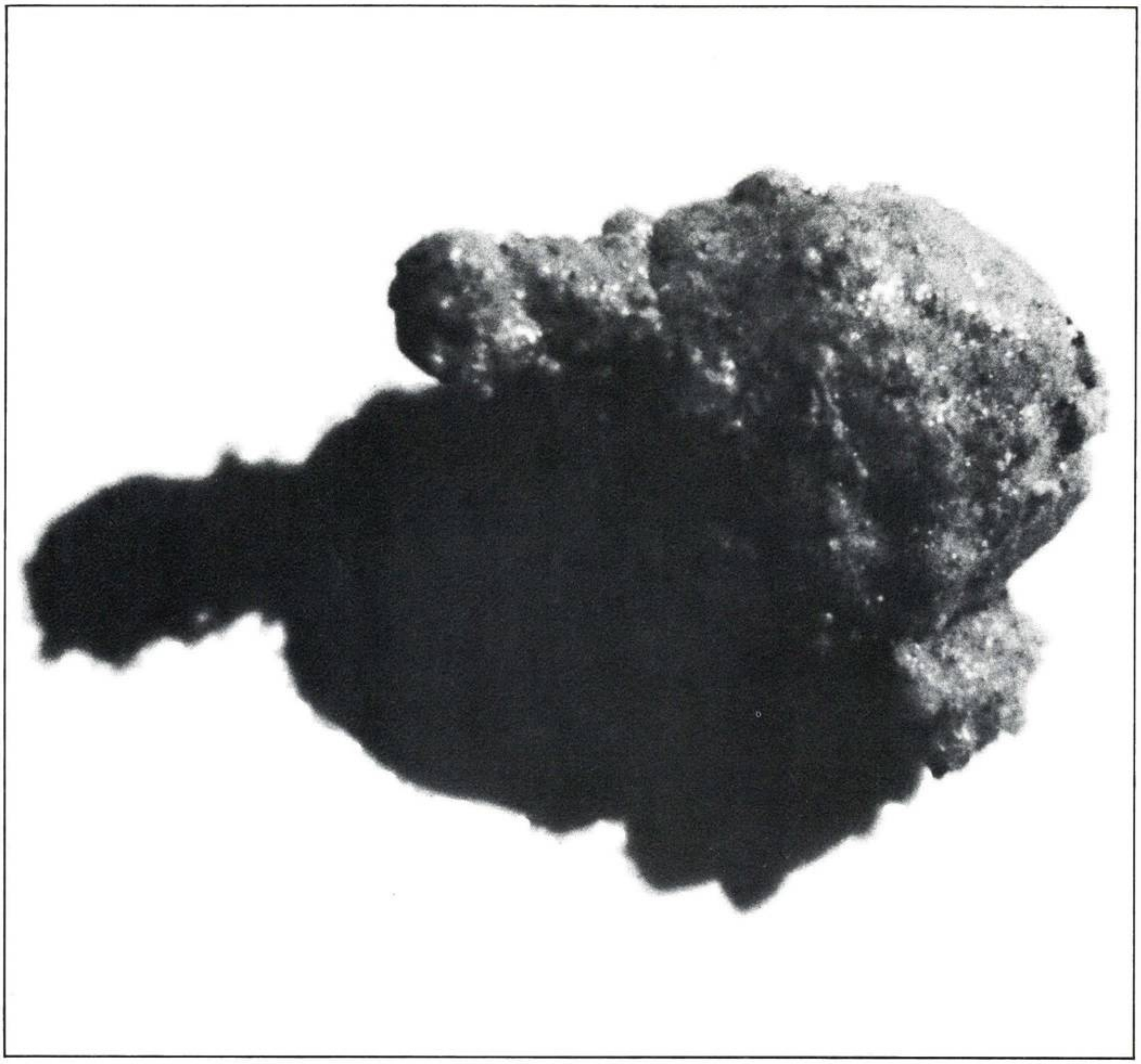
Additionally, comparison of meteorite chemistries reveals that groupings of meteorites originally came from the same parent. Another destructive process produced the now familiar craters of the moon and Mars, and other solar satellites. These were produced when small objects fell onto much larger ones, and inconceivable numbers of these events have occurred. Every hit makes a crater, so it is not hard to understand why craters are the dominant landform in the solar system.

From the pitted surface of the moon and pocked surfaces of Phobos and Deimos, to the vast punched out depressions on Mercury, Mars and Venus, craters abound. Earth did not escape, although its restless churnings have obliterated all but the most recent craters. (See "Baptism of Fire" in ASTRONOMY, September 1975.)

Thus, luck certainly was a factor in determining which pebbles grew into planets. It seems likely that even very large early bodies may not have survived the fierce competition. Rocky and icy matter may have shattered, accreted and reshattered before the final planets formed. There may have been several generations of planetoids — perhaps as large as the moon — that formed and were destroyed before the present planets appeared. It is no wonder that the very earliest silicate particles were hard to find!

The final stages of planetary formation were rapid and heavily influenced by gravity. Certainly, when the largest body in any zone grew beyond a few hundred miles across, its gravity became an important aid in pulling in other passing bodies. It no longer acquired only those intercepted by its cross section. By pulling in other bodies, it grew to planetary size very rapidly.

Growth to planetary size may have taken only 1,000 years, and certainly no more than some tens of millions of years. Compared to the history of the solar system, these are brief timespans. If the sun did, in fact, form 4.6 billion years ago, all the chemical and dynamic processes that produced planets were completed more than 4.5 billion years ago!



Debris from an experimental explosion of 500 tons of TNT formed tiny spherules like this from molten silicate material. These spherules collided and stuck together in free fall, possibly duplicating early accretion processes in the primordial solar nebula. Photograph by William K. Hartmann.

In other words, these formative years occupied less than one percent of solar system history. (Lunar samples tell us that cratering persisted intensely until about 3.9 billion years ago, but that was merely the final sweep-up of leftover debris.)

And so, the combined efforts of individuals from many fields have presented a much clearer picture of the formation of the solar system than was available even a decade ago. By evaluating processes involving chemistry, magnetism, isotopes, celestial mechanics, impact physics and astrophysical observation, researchers have formulated a rather precise recipe for the baking of a celestial cake.

An eclectic effort with fascinating results — not only a remarkable scientific feat, but a significant social feat as well. It is a tribute to our civilization that study of the solar system's evolution supported research in these many diverse disciplines at the same time. Multidisciplinary research allowed the individuals involved to interact — to stimulate each other — bringing their common results to bear on the tantalizing question of where the planets came from. Their conclusions tell us that the evolution of the solar system is a rather normal stellar happenstance. This, in turn, leads to the exciting assumption that the same process is producing similar systems throughout our universe!

Dr. William Hartmann is a senior scientist at the Planetary Science Institute in Tucson, Ariz., and currently serves as a visiting professor of astronomy at the University of Hawaii in Honolulu. He is author of the introductory text, **Moons and Planets** *(Wadsworth Publishing Co., 1972), and co-author of* **The New Mars**, *an illustrated NASA account of the Mariner 9 mission.*

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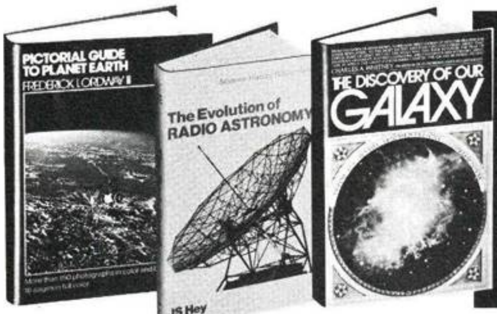
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COLONIES IN SPACE

by

Eric Burgess

When the Eagle landed at Tranquility Base, man had indeed taken a giant step. Fledgling though it was, it proved man could survive and be productive on the surface of another of the sun's satellites.

Man's venture into space is so significant that it has been called an evolutionary step comparable to that of life moving from the sea to land.

While the evolutionary aspects of the achievement may well take centuries to come to full fruition, many more practical benefits can be realized within the lifetimes of most of us.

Space colonization offers possibilities for bringing great new wealth and opportunities to the people of Earth. In addition, it offers these prospects without the characteristic threat to our environment that has accompanied such growth so often in the past.

What an exciting opportunity! Space offers the promise and hope of almost limitless resources if mankind can but learn to harvest the bounty of the solar system. To remain Earthbound, man would suffer from the limited nature of his planet's resources. Growth beyond terrestrial confines into the solar system and subsequently into the virtually unlimited galaxy and universe is the attractive alternative now offered the peoples of our world.

Our need for this new frontier is obvious. Mankind is gradually but steadily enclosing the remaining resources available to him; land, production capability, energy production and water are moving inexorably under the proprietary control of governments and large corporations. They are becoming increasingly less available to individuals, as the few remaining economic elements are being gobbled up.

Thus, with a finite supply of resources and a frail balance in its atmosphere, Earth itself has imposed outer limits on the growth we can realize while confined to our planet's surface.

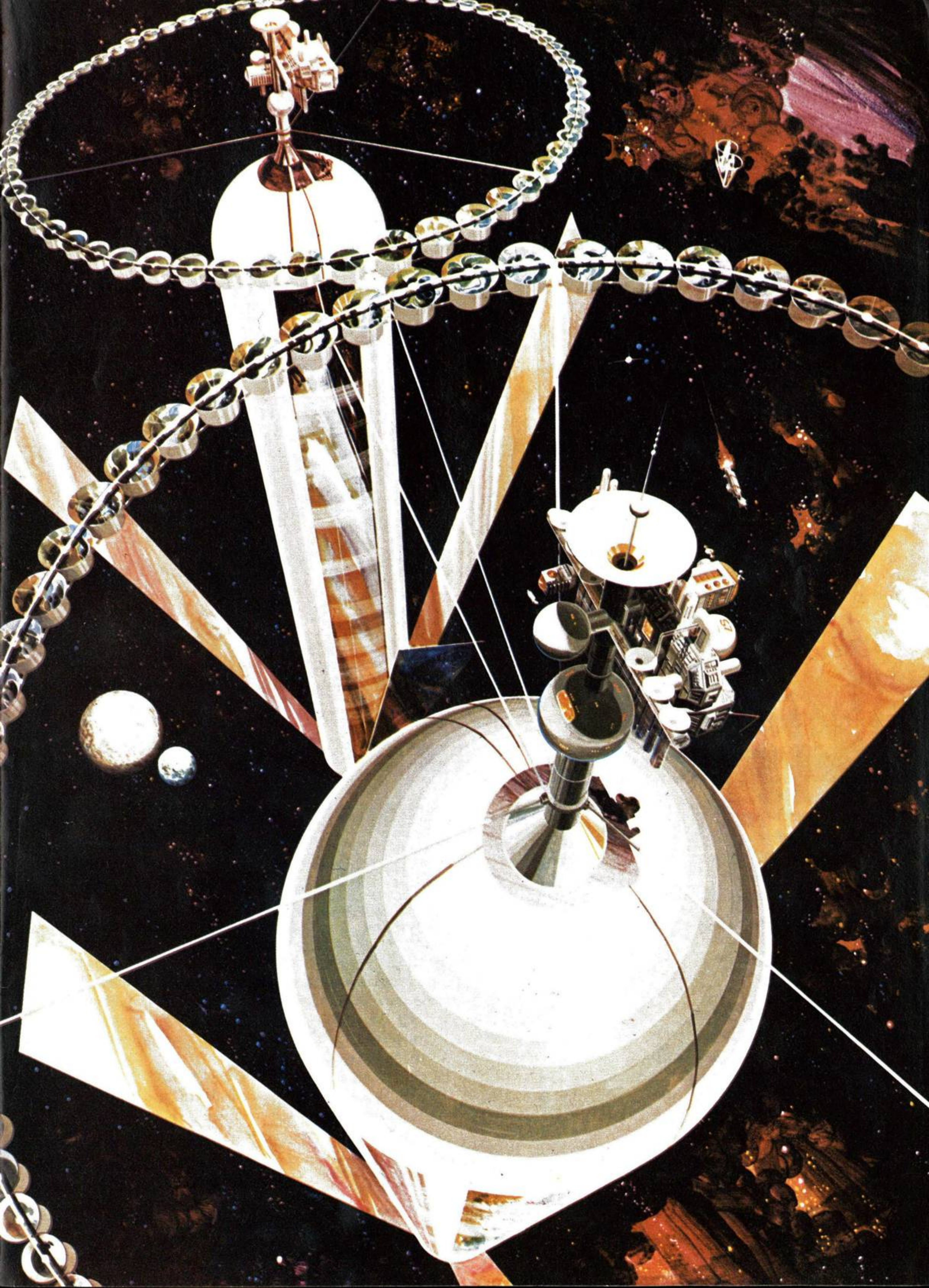
Exacerbating the situation is the fact that as knowledge increases, so does our use of raw materials. In the last 30 years, mankind has consumed global resources and raw materials at a prodigious rate. Ironically, these 30 years parallel the history of the United Nations, and more people of Earth are hungry, sick, shelterless and illiterate than when this forum was founded.

Also in these three decades, more of Earth's natural resources have been used up than over the whole of previous human history! It is apparent that such tremendous consumption cannot continue for much longer. Man's voracious appetite for resources and energy has resulted in a concomitant production of waste, polluting the environment as at no other time in history.

These facts reduce the opportunity for further growth on Earth. Unfortunately the great masses of underfed, underprivileged humanity see growth of some kind as the only way for them to achieve a higher standard of living. Growth to them and to most of us is essential; zero growth is attractive to only those who already have more than they really need.

Realistically, limiting growth is unacceptable. Such a reversal of traditional economic patterns would inevitably reduce living standards in the in-

This is the largest of the four space colony models proposed by Gerard K. O'Neill. The two cylinders pictured are 4 miles in diameter and 19 miles long. They could provide living space for as many as several million colonists. NASA painting.



dustrial world and severely restrict the opportunities for improving the living standards in underdeveloped nations.

Technology conferences in the early 1960s showed that the obvious alternative is to supplement Earth's dwindling resources by making use of materials from the moon, asteroids and other planets.

To restrict our civilization to Earth and thereby accept the resultant limitations on humanity's future development is illogical. The potential of using the plentiful materials and energy of the solar system has been demonstrated by nearly two decades of space research. All that is needed now is a concerted effort to apply what has been learned during these first ventures into the space age.

If we take a broad view of our recent accomplishments in space, we see that the landing of the Eagle on the moon was only our first step in a journey that will lead to actual colonization of the moons and planets of the solar sytem. Emigration into space will provide humanity with options and new frontiers that are desperately needed in a world that has lost many of its frontiers.

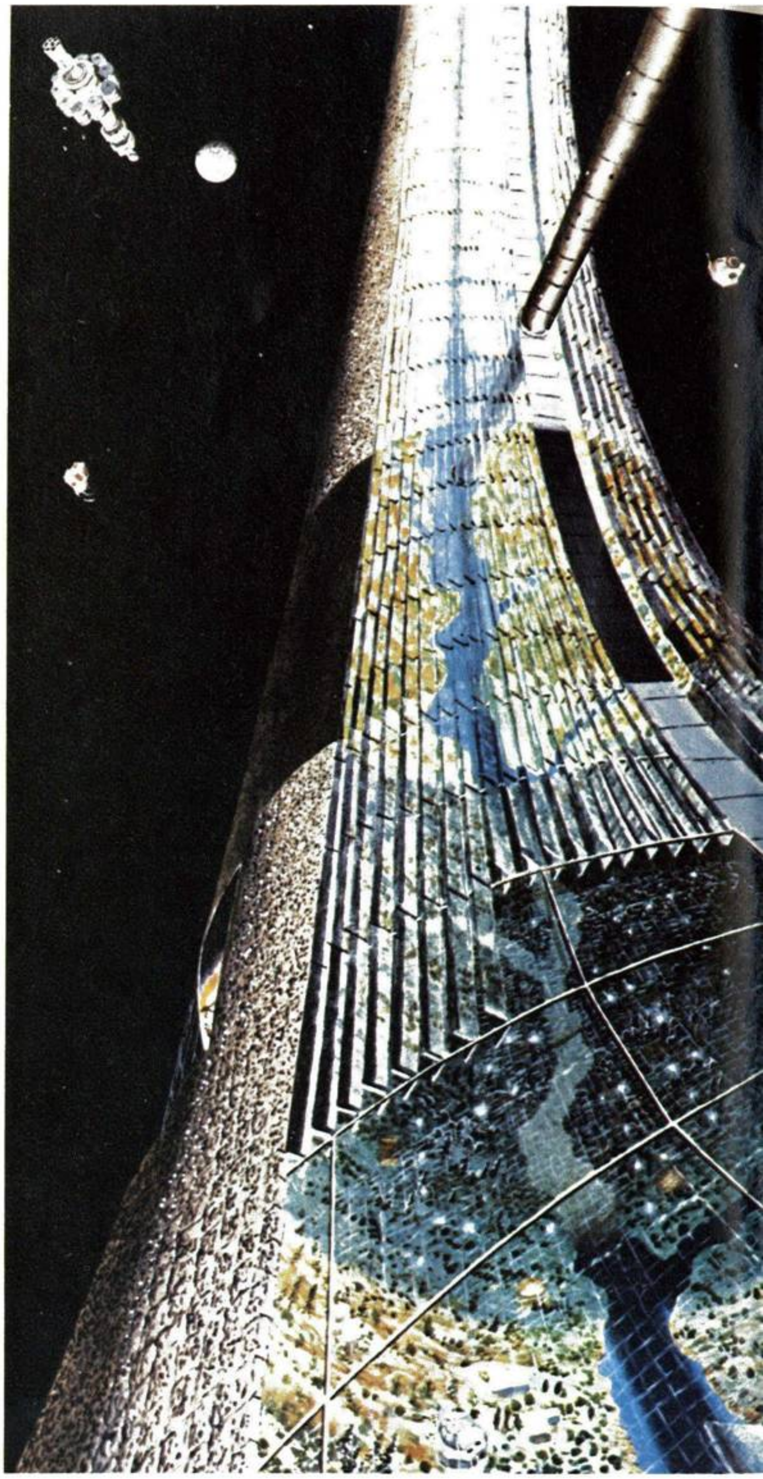
The great beauty of this alternative is that there is no current need for zero population growth in space. It will be possible to build new colonies in space faster than human populations can grow. Of course, some scientists have correctly pointed out that interplanetary colonization will not relieve Earth's growing pains.

Never in the past has expansion into a new territory relieved the population pressures in the old. While this is true, the major advantages of expanding has always been to provide new frontiers in which separate *economic* growth can continue.

Such capacity for further growth is essential to human development to avoid stagnation. As new frontiers are settled, new ideas and concepts are born and tested. Later they are fed back to overpopulated areas where they ameliorate the adverse conditions thereby breaking the bonds of intellectual inertia.

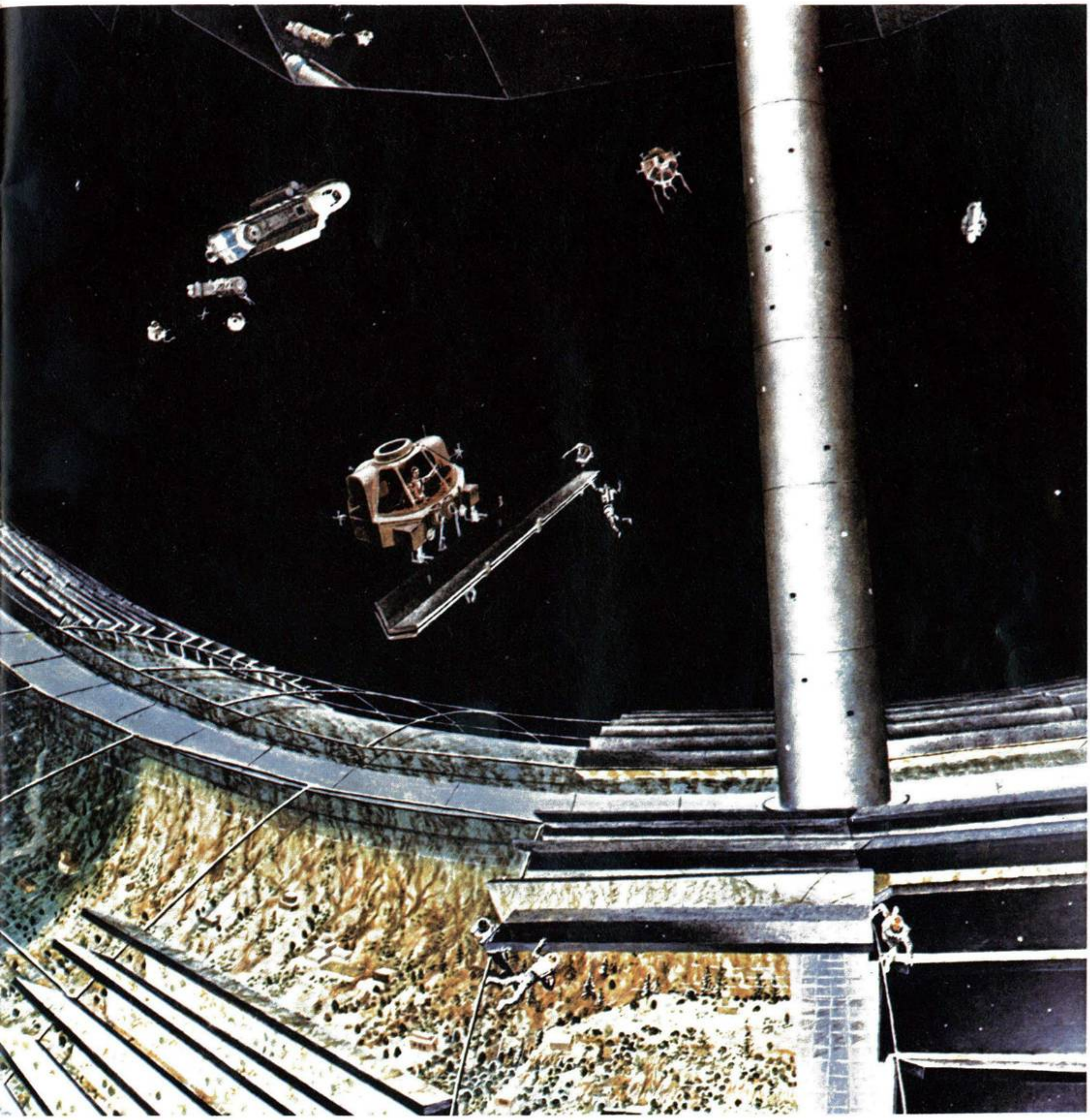
When viewed in this light, space colonization and development immediately frees mankind from severe restrictions by broadening his resource base immensely. As important, the modern industrial world is not confined to the terrestrial whole. Space colonization, therefore, offers a way out from this sense of closure and limitation that now threatens the mental, physical and intellectual well-being of the people of Earth.

Although the benefits seem obvious, the very practical matter of financing must be dealt with. While the idea of moving into space stimulates the imagination and can produce considerable public interest, very large sums of money must be marshalled to construct the first space colonies. Given our present political and economic systems, it will be a major — though not insurmountable — task. By way of comparison, the project magnitude of the simplest space colony is greater than the largest free enterprise venture on Earth — the Alaska pipeline. Its cost would be similar to the invasion of Europe during World War II.



The cost of a power generating satellite is approximately $60 billion for research and development, followed by $13 billion for each satellite and its ground receiving and power conversion station. Assuming that the electricity these satellites generate will be priced competitively, the satellite power system could be paid for in 30 years. This is similar to the investment return realized for nuclear and fossil fuel systems on Earth.

Developing artificial satellites to house entire

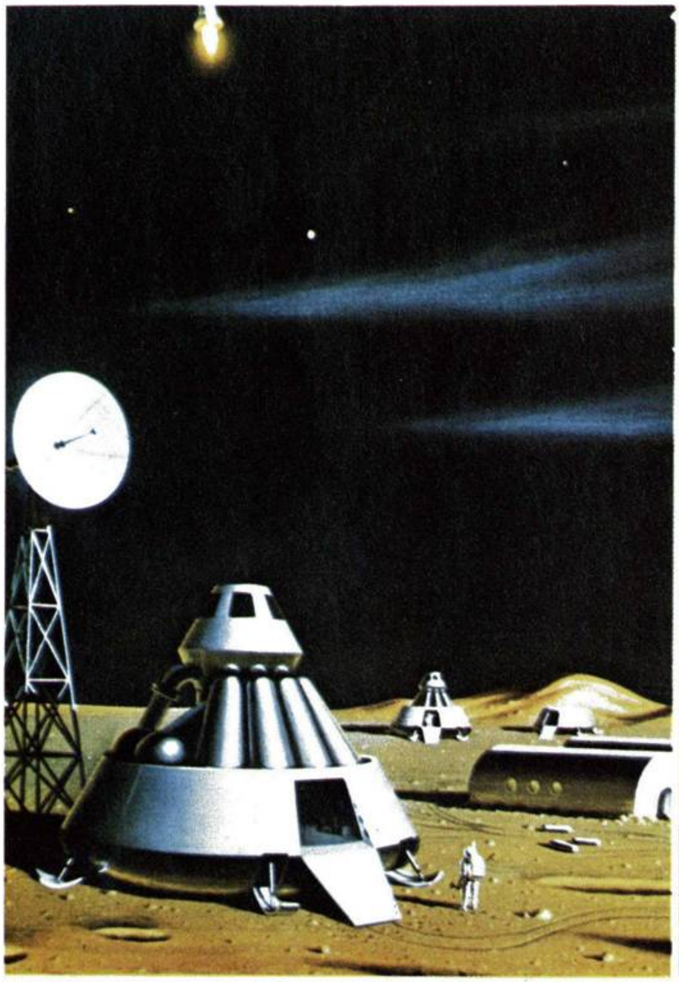


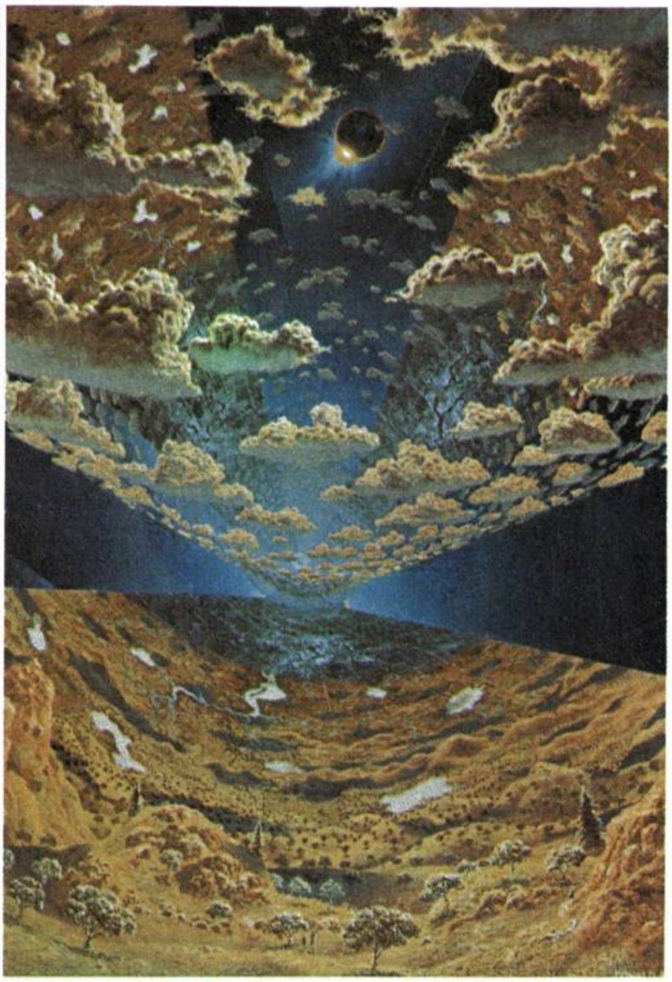
space colonies represents an attractive opportunity to economically bootstrap mankind into space; a financial seeding from Earth will provide a beachhead from which additional space colonies will be spawned. During peak development, an investment of nearly $10 billion per year will be required.

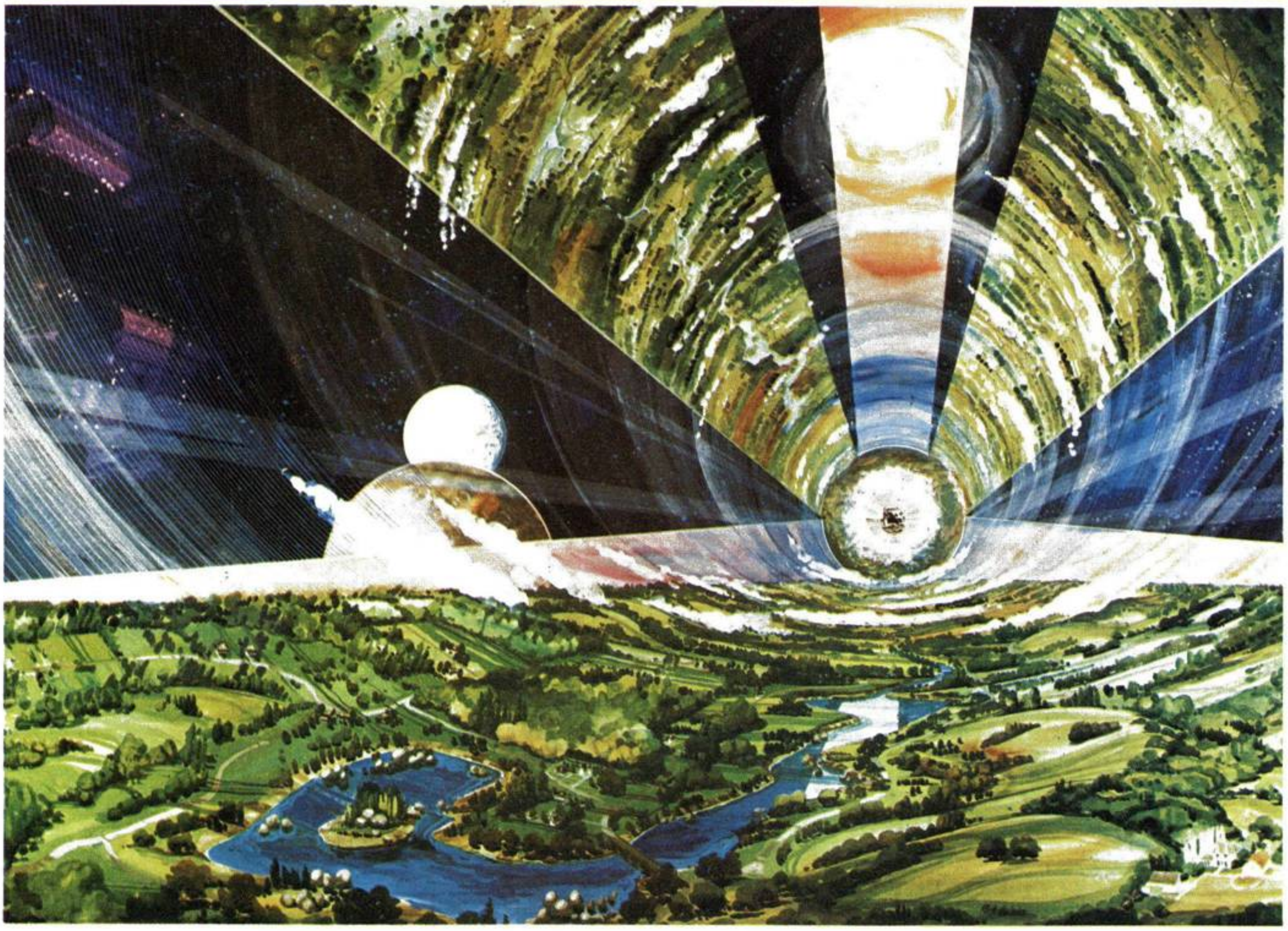
Some scientists envision such a project as logically involving the establishment of three satellite colonies. The total cost for the trio is estimated as $106 billion. Research would consume $1.5 billion; development to the first unit stage, $19.7 billion; transportation, $50 billion; administration and miscellaneous, $21.2 billion; additional units, $11.1 billion.

Space-suited workers are placing louvers over the "sky" side of a torus habitat. Made of slag from the processing of lunar materials, the louvers will protect the habitat's colonists from cosmic rays. They also will regulate the amount of sunlight reflected from the large mirrors shown in the upper right of the picture — giving an artificial cycle of day, night and seasons. NASA painting.

Even though this seems to be a fantastic amount of money, the colonies — in satellites, on the moon and elsewhere — will be self-sufficient in many ways. While they will have to import many things from Earth, they will export processed materials and converted solar energy. It is very likely that they will have a most favorable balance of payments, because







they will be in the middle of a burgeoning space industry. The colonies will be building things that can be used in space and on Earth including Earth satellites, planetary probes, power generators, other colonies, starships, and manufactured products for Earth that make use of the hard vaccum and/or zero gravity of space.

Direct manpower requirements of the first colonies are not great. To build Earth support facilities will take 70 people four years; 50 people will need one year to build the facilities for use on the moon; construction of the radiation shield for the satellite-based space colony will require 10 years and 1,100 people; the shell for the living quarters will occupy 1,200 people for six additional years; completing the habitat interior will require the skills of 325 people for four years. Certainly, the project will be a sound financial investment — both on Earth and in space.

The first detailed assessments of interplanetary colonization projects were made during the early 1970s. These studies accented construction of artificial habitats in space — space stations — rather than colonies on the moon and other worlds. Even so, these most recent views of man's movement into space depend on moon bases so that lunar resources can be used to build the space stations.

The first space colonists could be living in their artificial "home" in 20 years, with two more space satellite colonies operating in 30 years. Each of these Earth suburbs would accomodate 10,000 people, so we could have more than 30,000 pioneers in space shortly after the turn of the century.

Essential requirements for interplanetary colonization include development of an efficient, inexpensive means of travel into space, and design of functional life support systems to keep colonists alive and comfortable.

As originally conceived, the Space Shuttle program (currently being developed by NASA) was intended to be an inexpensive answer to space transportation needs. Unfortunately, as succinctly put by Arthur C. Clarke, fiscal restrictions have caused the Space Shuttle — once hailed as the DC-3 of space — to be "degraded... to the DC-1-1/2". The Space Shuttle now being built does not provide the ultimate key to effective space transportation. Nevertheless, it will enable us to gain enough experience in transportation systems to develop new and better ways of moving payloads into space. No doubt its technology will be the basis for our initial colonization efforts.

Colonies on the moon and in Earth orbit will serve as steppingstones to colonization of other planets. The picture at upper left is a fledgling Martian colony. Metal for the pressurized huts and landing vehicles was probably mined on the moon; most of the manufacturing was done in orbit. The other two paintings are artists' impressions of the view from inside the space colony pictured on page 19, showing different artificial seasons. The first generation of colonists might have difficulty getting used to the sight of two masses of land hanging upside down in the sky. Upper left: Artwork by David Hardy. Upper right and bottom: NASA paintings.

For example, heavy-load launch vehicles could make use of engines developed for the shuttle to carry building materials from Earth to low orbit. Here, launch vehicles would rendezvous with space barges which transport the materials to the construction site of the space colony.

Insofar as life support systems go, there are numerous possibilities. They range from the simple systems used today in Skylab and other space vehicles to complete recycling systems that can support whole cities in space and on other worlds. Food, water and oxygen — the primary materials needed to support life — can be supplied at least initially by Earth. However, such a method is suitable for the short term only.

Daily per person consumption in an extraterrestrial colony will be about 1.5 pounds of food, 4.77 pounds of water, and 1.96 pounds of oxygen. Balancing this total consumption will be an average per person daily output of 8.23 pounds of wastes. Since water is the main material that must be brought to the base, for the long term, water conservation and reclamation from wastes will be imperative. Unlike water, food can be grown; oxygen can probably be obtained from the planet's rocks.

Manned interplanetary flight becomes economically feasible only if spacecraft can refuel on other worlds. This means it will be necessary to develop modular propellant production plants that can be easily transported to other worlds where they will manufacture fuel from the planets' surface materials. Similarly, portable human bases to support local production facilities will have to be designed.

Interplanetary transportation between Earth and Mars might require a lunar propellant processing plant to produce 2,000,000 pounds of oxygen and hydrogen for each round trip. But if these gases could also be produced on both Mars and its satellite Deimos, the load on the plant would be considerably reduced. The most difficult problem to solve is locating sources of hydrogen on the other terrestrial type worlds. However, a Mars journey refueled at a lunar base alone would require only 1/5 the total amount of propellant needed for a direct flight from Earth. Obviously, the savings are tremendous.

With refueling bases on the moon, Deimos and Mars opened in stages, interplanetary manned journeys to develop major colonies on other terrestrial type worlds of the solar system could be accomplished with foreseeable technology. Logical candidates for colonization include the moon, Mars and its two satellites, the Galilean satellites of Jupiter, Titan, major asteroids and Mercury.

One possible exception is Io, which is too deeply immersed in radiation from Jupiter to allow effective, near-surface protection. Venus will also be difficult to colonize without modifying the planet's environment extensively. While Venus' high atmospheric pressure may not be a difficult problem to solve, effectively dealing with surface temperatures hot enough to melt lead make the planet a less likely candidate for immediate colonization. Even Mars, the most hospitable of planets — with a thin, carbon dioxide atmosphere — will require colonists to don fully pressurized suits whenever they leave the protective shell of their environmental womb. As in all extraterrestrial settlements, Martian colonies will have to be enclosed within pressurized structures.

But even before we set foot on the scarps of Mercury or canyonlands of Mars, or dream of a final solar system outpost on Pluto in our journeying to the stars, we must establish the technological and psychosocial groundwork for that greater colonizing effort.

Logically, the first planetary body we will colonize will be the moon, where a base with about 25 people could effectively support a fuel production plant. The cost of establishing a permanent base of this type on the moon (or Mars) will be economically feasible only if it is possible to use local resources.

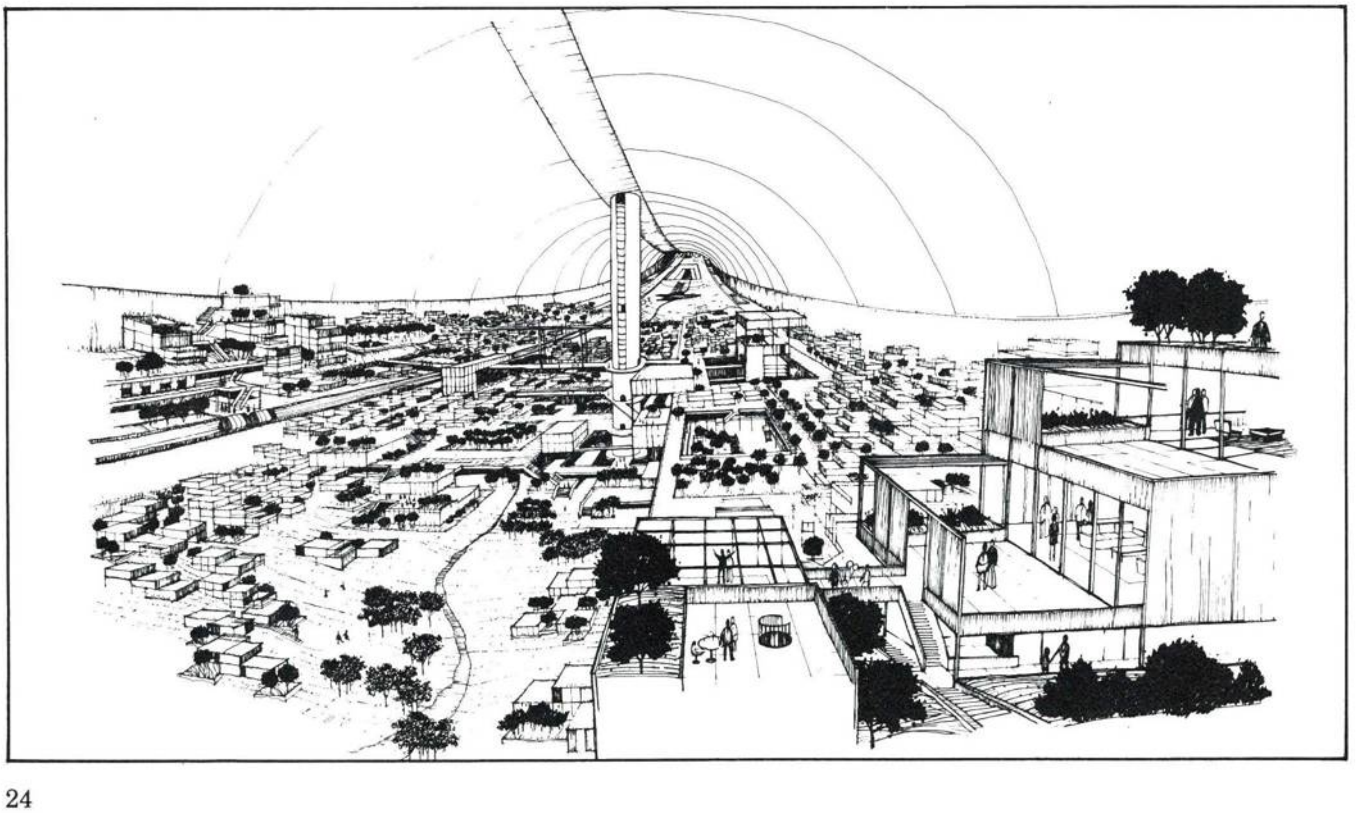
The first lunar bases might be little more than a gathering of simple modules sent unmanned to the moon and guided to a landing from Earth. Some of the modules might carry remotely controlled vehicles that scoop up soil and dump it over modules to provide colonists with protection from the harsh lunar environment.

Lunar bases are envisioned as being of two basic types. The first is a small base used for short periods. Similar to the early bases in Antarctica, the essential features will be a life support module and living/working modules. Three or four people could spend several months without having to wear spacesuits except to transfer from one module to another. The second type of lunar base will be suited to a permanent moon colony. Again constructed of modules, the permanent base will ultimately use material fabricated from lunar resources.

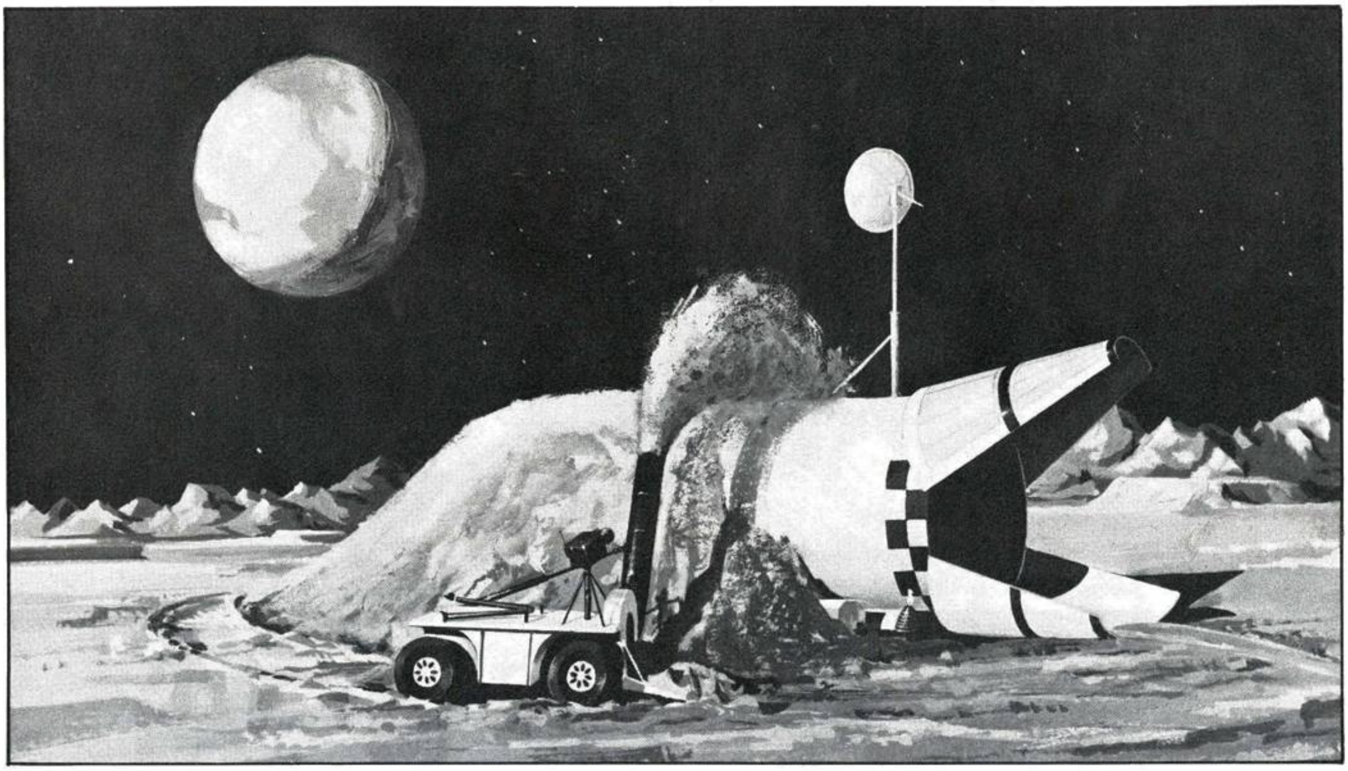
The variety of possible uses for a permanent moon base indicates how well suited this unique environment is for many purposes. It has been suggested that a new industrial revolution could be based on the moon, where it would be free from the environmental problems of heavy manufacturing. Just 250,000 miles from Earth, the moon's 3 million square miles of undeveloped territory is tantalizingly close. It offers a convenient location (in space age terms) for use of vacuum technology, "dirty" manufacturing processes, mining of minerals in short supply on Earth, for scientific labs, and radio and optical astronomical observatories.

Although it is costly to transport materials from Earth to the moon, the reverse is not true. The cost of transporting lunar materials to Earth is not very much greater than that of transporting air freight across the Atlantic Ocean. Consequently, if minerals or metals or fabricated products are found or produced on the moon, transporting them to the home planet will be economically feasible.

Of course, once a permanent base is established on the moon, it will only be a matter of time before its unique recreation and vacation possibilities will



This inside view of the torus shaped space colony illustrates a housing area. The river seems to run uphill, as the ground level curves away to be cut off by the "sky" side of the structure. This design could accommodate up to 10,000 permanent inhabitants in an Earthlike — though totally controlled — environment. NASA drawing.



Early lunar colonies might depend heavily on Apollo-developed technology. Here a robot vehicle, controlled by scientists on Earth through television and telemetry, covers a survival shelter with lunar soil. The layer of soil will protect the first colonists from meteoroids, radiation and temperature extremes. Douglas Aircraft Co. artwork.

be in great demand by a space age jet set. With unusual scenery, low gravity and the unforgettable sight of brilliant Earth shining in a jet black sky, the moon certainly has many exploitable attractions for the tourist.

Following the permanent settlement of the moon, the next stage in colonizing the solar system will undoubtedly be construction of artificial planets. The technology to do so will have been generated by operations on the moon and large space stations in Earth orbit.

One design for such an artificial planet consists of a wheel shaped space station over one mile in diameter that would house 10,000 people. It would simulate Earth's gravity by rotating at its hub once per minute; its rim would have enough room for recreation facilities, stores, schools, light industry and agriculture. Outside the wheel — to make use of the weightless, airless manufacturing arena — the colony's initial heavy industry would be the manufacture of other colonies and power satellites, as well as ore processing from lunar mining operations.

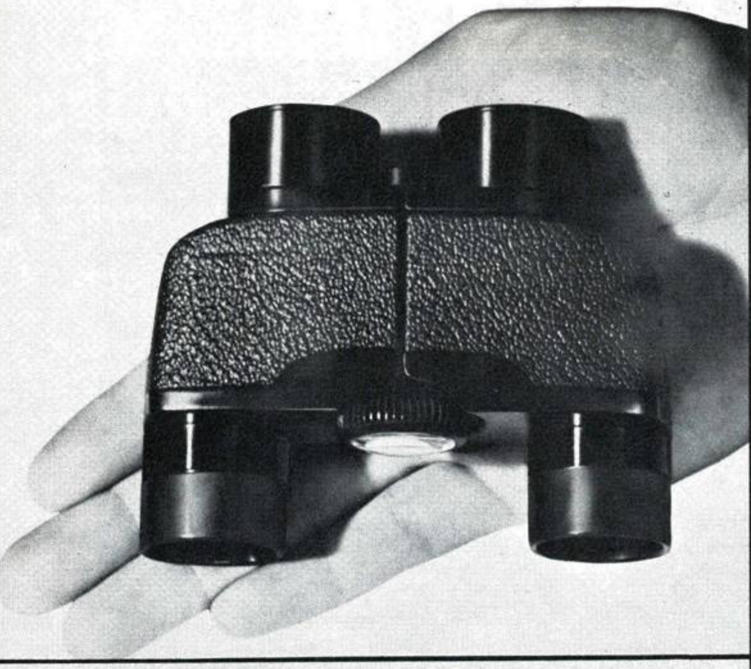
During the early years of space colonization, the number of colonies will grow rapidly. Rapid social change and expansion of cultural options will characterize space colonization. Initial population will consist of vigorous young adults in their prime working years, with comparatively few children and older people. While space colonization parallels frontier history on Earth in some respects, there is one very significant difference.

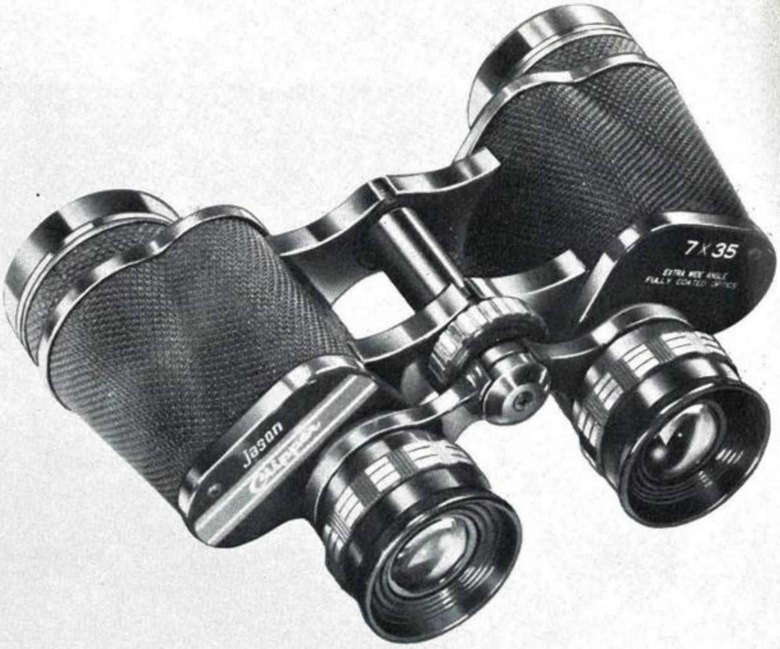
Earth frontiers have tended to attract renegades, outlaws and unskilled people of all ages. Space frontiers, on the other hand, will require only highly trained, motivated and skilled workers. Antisocial and erratic behavior cannot be tolerated, because the physical safety of the group will always be of primary concern. As a consequence, all prospective colonists will be rigorously screened.

Colonization of space remains one of the most significant and dramatic events in the history of man. Not as an outlet for mass migration, opening space will gradually move from Earth all those production processes that are ecologically incompatible. Based on economic resources that are not a part of Earth, colonization will be responsible for improving worldwide living standards that make it possible for the masses to appreciate Earth's unique beauties.

And, when colonists find the solar system has become uncomfortably crowded, they will have an attractive option. The stars will always beckon, and one of the artificial worlds that has been home will become starship Eagle. Mankind will take another fledgling step...this time to the stars. ◆

Eric Burgess is a member and was the first chairman of council of the British Interplanetary Society, and helped form the International Astronautical Federation. In 1949 he published the first technical paper on unmanned Earth satellites in synchronous orbits for scientific/communications purposes, and in 1951 wrote the first technical paper on a photo probe to Mars. More recently he originated the idea of sending a message to extraterrestrial intelligences via Pioneer 10.

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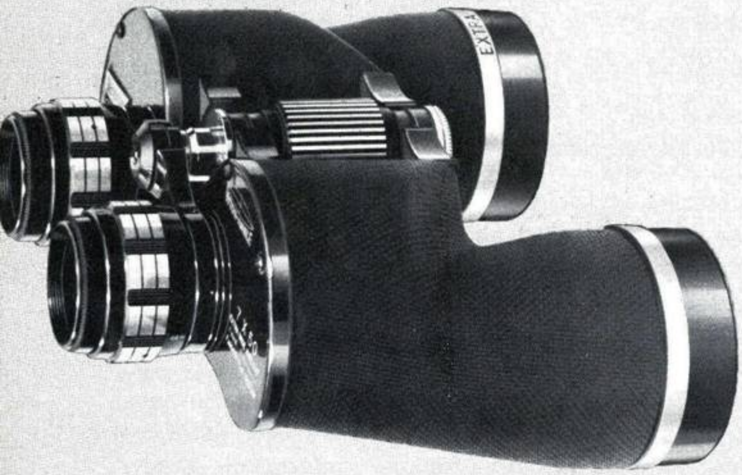
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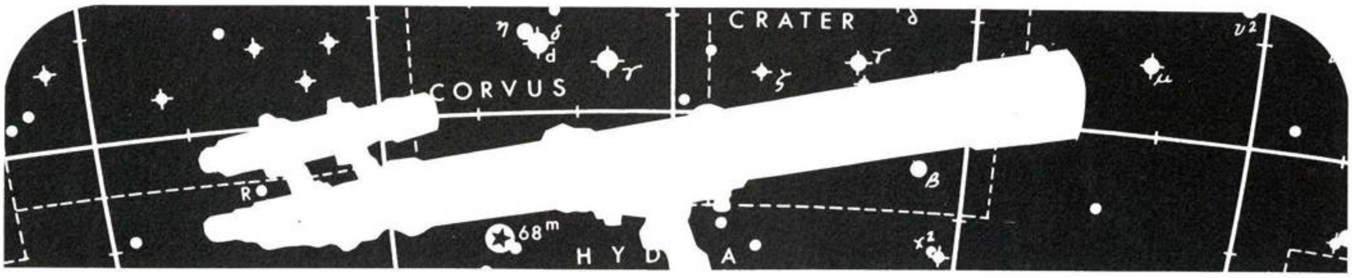


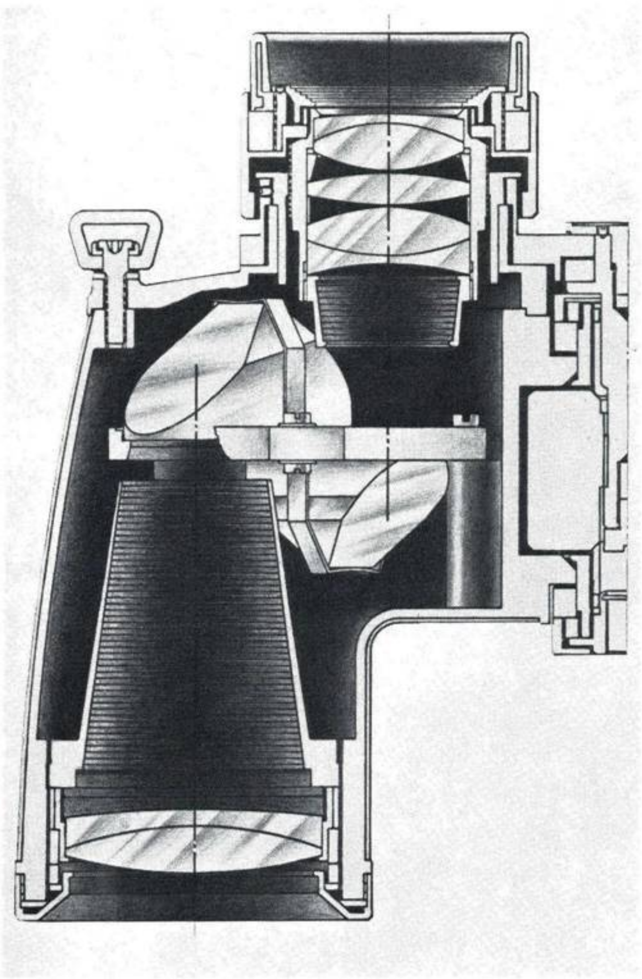
Binoculars for Stargazing

by

James Mullaney

The binoculars on the opposite page show the range of commonly available (and astronomically useful) powers and apertures. At upper left is the Bushnell Custom Compact 6 x 25 ($120); this is a useful instrument when space and weight are at a premium, but has little light gathering power. At top right is a 7 x 35 model (Jason #188, $57.50), which is also relatively lightweight but gathers almost twice as much light. Most astronomy enthusiasts opt for the 7 x 50 — though the extra weight might discourage someone who mainly wants binoculars for nature study or sports. The two pictured in the center are the Jason Model 151 Extra Wide Angle 7 x 50 ($105) and the Bushnell Banner 7 x 50 ($100). More powerful binoculars are difficult to hold steady without a tripod, and have a smaller field of view — but they can be useful. Pictured at bottom are the Bushnell 10 x 50 Custom ($190) and the Tasco Mountaineer 20 x 50 ($99.95). Manufacturers' list prices are quoted. Photographs supplied by manufacturers.

Blazing star filled skies beckon observers with the tantalizing beauty and mystery their telescopes will reveal. But when those rare, still, transparent observing nights occur, the screaming brilliance of the stars, Milky Way and clusters may only be diminished by a telescope's magnification. Lowly though they may seem in the scheme of your equipment arsenal, such nights call for a good pair of binoculars. Combining extreme portability with the unsurpassed advantage of simultaneously seeing spectacular fields of view with both eyes, binoculars are excellent for learning your way about the sky as well as for more serious observing programs



A binocular's prisms serve two functions: to fold the path of light from the objective, making the instrument compact, and to "flip" the normal inverted image so that up and down, left and right appear as they do to your unaided eye. Bushnell Optical Co. drawing.

like hunting comets and studying variable stars.

What are binoculars? They are a matched set of reduced size refractor telescopes connected so you can look at the same object at the same time with both eyes. The obvious advantage for Earth based viewing is scene depth that only binocular vision produces. Because the moon, planets and stars are so far away, however, you don't gain true three-dimensional perspective with sky viewing. Instead, viewing star fields with binoculars gives a false impression of three-dimensionality stimulated by both eyes receiving the same image of the sky simultaneously — an impression that cannot be duplicated with a single viewing system telescope.

Binoculars consist of two independent, parallel optical systems in precise alignment with each other. Both objective lenses are achromatic with matching Kellner type eyepieces which are also achromatic. Between each optical path are matched prisms that serve a twofold purpose. First, they erect the otherwise upside down image produced by an astronomical telescope. Secondly, instead of just giving a right side up view like the right angle, star diagonal prisms supplied on small refractor telescopes, binocular prisms flip the mirrorlike image of a scene so that "right" and "left" in the binocular eyepiece correspond to right and left in the scene you are viewing.

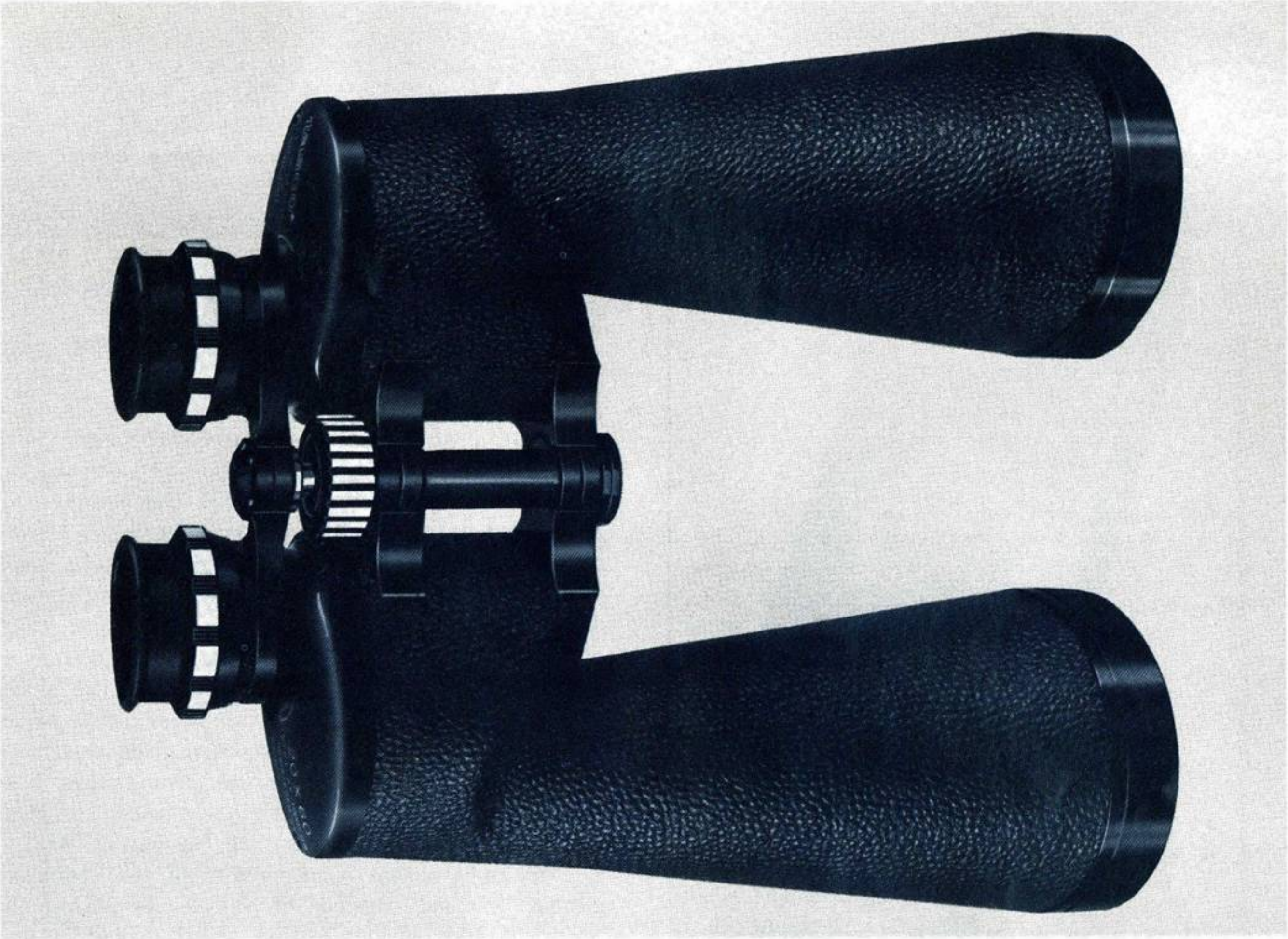
Parallel positioning can be changed to accommodate the different distance between various observers' eyes — by a tight friction connection between the two binocular elements. In this same area is a focusing mechanism that changes the eyepiece focus for both eyes simultaneously. Additional diopter focus is found usually in the left binocular eyepiece. Your eyes — when focused on infinity — do not produce equally sharp images. The diopter mechanism allows you to first use the central focus until the right image is sharp, and then adjust the diopter till the left image is equally sharp. Once corrected to your own diopter focus, you only need to use the main focusing mechanism to get equally sharp images for both eyes.

Binocular optical systems are internally sealed to insure precise alignment and a dust-free interior. However, if even slight misalignment occurs, it will result in eyestrain (and consequent headaches) and double images. Good binoculars are carefully inspected for this, as well as other possible defects during assembly. But if a problem develops, repairs should only be entrusted to experts in such matters since successful collimation is a tricky operation that requires special equipment and skill. With reasonable care, most binoculars will provide a lifetime of worry-free use.

True prismatic binoculars should be distinguished from less costly and often optically inferior opera or field glasses. These consist of two simple telescopes mounted side by side and are often referred to as imitation binoculars. While both types give erect or upright images for terrestrial use, opera glasses use negative eyepiece lenses to magnify the image produced by the objectives and give a very restricted field of view. Usually you can buy high quality prismatic binoculars for less than the cost of the smallest refractor telescope — making them an ideal first sky watching instrument for the raw, beginning

WHAT THOSE NUMBERS MEAN

Type	Power	(mm Size &	inches)
6x15	6	15mm -	.6"
6x30	6	30mm -	1.2"
7x35	7	35mm -	1.4"
7x50	7	50mm -	2"
10x50	10	50mm -	2"
15x60	15	60mm -	2.4"
10x70	10	70mm -	2.7"
20x80	20	80mm -	3.1"
20x120	20	120mm -	4.7"



With objective lenses equal to that of a small telescope, these 20 x 60 binoculars (Tasco No. 319 Super Spotter, $159.95) are powerful enough to see the rings of Saturn. NASA uses this size for missions like Apollo/Soyuz. Tasco drawing.

astronomy enthusiast. Their value does not stop there, however, because they are an indispensable accessory for the seasoned observer as well as maintaining their observational value even after the beginner graduates to his first telescope.

Sizes and Types

Specifications for binoculars are written as a sequence of numbers. For example, 7 x 35 is expressed verbally as seven by thirty-five. The first number and "x" is magnification. The second group of numbers is the clear aperture of the binocular's objective lenses in millimeters. In the example used above, these binoculars are seven power (7x) with 35mm aperture objective lenses (about 1.4 inches aperture).

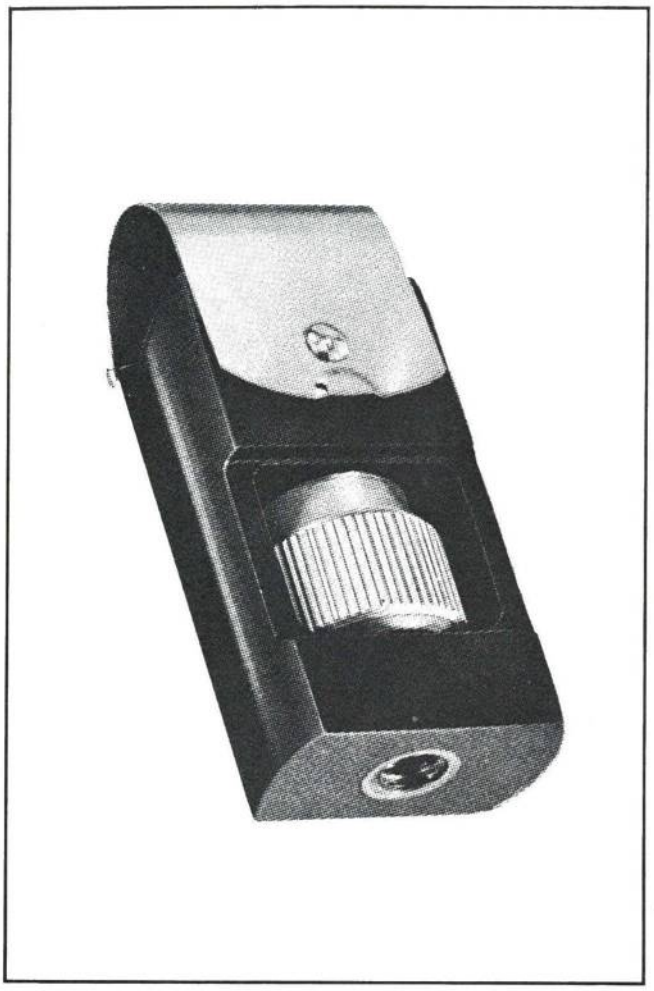
Just as telescopes vary greatly in size and style, so do binoculars. You will find miniatures having 15mm aperture objectives and weighing less than six ounces, and giant military surplus binoculars with objective lens apertures of 70 to 120mm, weighing many pounds.

While binoculars with specifications of 6 x 30, 7 x 35, 7 x 50 and 10 x 50 are generally useful for stargazing, most serious observers find 7 x 50s or 10 x 50s a good compromise between size, power and field of view. The larger aperture works best for low light levels encountered in sky observing. The additional magnification of 10 x 50s result in larger image size and a smaller field of view — though resolution is somewhat better than with 7 x 50s. Both are excellent instruments and either is a good choice for the astronomy enthusiast.

Larger aperture models provide greater light grasp, resolution and magnification than either of these. However, telescope size binoculars are quite heavy and difficult to hold steady without a tripod or other support. Increased power also means a reduced field of view which defeats this outstanding feature of binoculars.

Special types of binoculars include manual or electric zoom models (with typical magnification ranges of 7 to 14 power) and superwide-angle designs. While most binoculars provide six to eight degree fields of view (compared to the one degree field of most telescopes), wide-angle models boast fields as large as 10 or 12 degrees — 24 full moon diameters of sky! (Such fields are often given in specifications in terms of feet visible at 1,000 feet distance, and must be converted to angular measure.)

Center focus models tend to be somewhat sturdier than those offering individual focus adjustment



This adapter is used to attach a pair of binoculars to a standard camera tripod to eliminate hand held vibrations. It's hard to use high power, large aperture binoculars for any length of time without such an arrangement. Mayflower photograph.

for each eye. However, if center focus binoculars do not have a diopter adjustment, individual eyepiece focus is a useful alternative because in effect you can accomodate and correct the individual focus of your eyes. Unless you suffer from astigmatism, for greater comfort try observing without your glasses if you usually wear them. For simple near or farsightedness, focusing the binoculars normally provides the needed correction.

Accessories

Comfortable viewing with binoculars includes two invaluable accessories. The first is a chaise lounge or reclining chair that you can take outside at night. An inexpensive aluminum tube, plastic weave lawn chaise will allow you to lie back comfortably for easy observing of most of the sky – particularly the zenith – without straining your neck and body. Since most of us suffer from the shakes after a few moments, viewing the sky with binoculars from a reclining position gives support to the binoculars and keeps your hands and arms from becoming tired as quickly.

Another inexpensive accessory that probably allows you to double the usefulness of equipment you already own is a binocular tripod mount. Adapters cost between $5 and $8 and are available from Edmund Scientific, University Optics and Colonial Optical Co. You might also try camera stores or departments. Generally, tripod mounts fit all standard size binoculars and are designed to be attached to most photographic tripods in order to eliminate hand held vibrations. With larger aperture, higher power, heavier binoculars, tripod mount adapters are almost a necessity.

Virtually every celestial object can be enjoyably viewed with binoculars. Lunar surface features provide fine sights with higher power models, while eclipses of both sun and moon are best observed with such instruments. At 7 or 10 power you can see the thin crescent of Venus and watch the satellites of Jupiter (though here, higher magnification is recommended). Also, you can track from night to night against the sky background the slow daily movement of all the planets (except Pluto) and brighter asteroids. Frequent and beautiful twilight conjunctions of the moon and bright planets are often superb binocular sights. Rounding out the solar system are comets – some of which have been discovered with 10 x 50 binoculars. In general, comets are best viewed – especially those with long tails – in such instruments (see Gazer's Gazette, November 1975).

When it comes to the realm of the stars, an almost limitless number of objects lie within the reach of binoculars, including bright variables and highly colored stars, wide double and multiple stars, open and globular clusters, bright and dark nebulae, and even many galaxies. Perhaps the grandest sight of all is our own Milky Way galaxy – an incredible profusion of suns seen in binoculars as in no other type of optical instrument. All of this and more awaits the binocular user!

Even though all celestial objects are technically at "infinity" and therefore too distant to show depth perspective, one of the surprises and delights of binocular viewing you will encounter is the breathtaking view of the moon seemingly suspended three-dimensionally against the star background. Although only illusionary, the effect is nevertheless real and dramatic.

Astronomy with an Opera Glass by Garrett P. Serviss can still be found today in many public libraries. Another reference – readily available in most bookstores – is **Field Book of the Skies** by Olcott and Mayall. In addition to its well-known roster of telescopic wonders are charts of each constellation showing hundreds of binocular objects.

With a good pair of binoculars around your neck, you are ready to embark on a nightly journey of celestial exploration into realms vast and beautiful. And through the portholes of your binocular spaceship, you will enjoy views of heavenly splendor unmatched by any telescope – however large it may be!

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FOR SALE — Minolta SR-1 35mm SLR camera, 55mm f/2 lens; $100.00. Hexacon (Praktica) 35mm SLR camera, 50mm Meyer f/1.9 lens; $50.00. Contact John J. Brooks, P.O. Box 645, Mt. Shasta, CA 96067. Phone (916) 926-3204.

FOR SALE — Variable speed motor declination drive for any telescope with hand tangent declination control. Includes 12 volt, 70 M.A. motor, gear box, clutch, rheostat, instructions. Will turn declination worm from 1 to 1/5 rpm. Price: $30.00. Write Bill Buffinger, 309 N. Alpine Dr., Beverly Hills, CA 90210.

FOR SALE — Accessories for 3-1/2" Questar. Declination vernier drive; $50.00. Piggyback camera mount; $40.00. Or both for $80.00. Write Frank L. Calloway, 1211 Darby St. - #2, Colorado Springs, CO 80907.

Advertise it free in Astro-Mart.

FOR SALE — 10" Cave custom deluxe Newtonian, chrome plated, electric clock drive, declination slow motion, 2 oculars. Mint condition; housed in observatory. Price: $600.00; will deliver within reasonable distance. Contact Anthony Vaquero, 233 Slawson Dr., Camillus, NY 13031. Phone (315) 487-6351.

FOR SALE — Zeiss Jena 7 x 50 binoculars with leather case, mint condition; $235.00. Ross Naval 7 x 50 binoculars with case, good condition; $140.00. Write Bill Mecca, 1527 Madison Ave., Dunmore, PA 18512.

FOR SALE — Criterion Dynatracker variable speed drive and slow motion controller. For use with any synchronous electric drive (AC or DC) telescope shown in Dynamax 8 ads. Contact Dave Meyer, Stuart Towne Apts. - #7-B, Beaufort, SC 29902. Phone (803) 524-9472.

FOR SALE — Sears 3" refractor with equatorial mount, slow motion controls, 5 eyepieces, Barlow, erecting prism, star diagonal, sun screen, solar and lunar filters, tripod, accessory tray, light mahogony case. Price: $150.00. Contact Tom Corcoran, 1072 Highland St., Baldwin, NY 11510. Phone (516) 546-0826.

continued on page 49

Viewing Saturn

In any telescope — large or small — the ringed planet Saturn is the most breathtaking sight in the solar system. When Saturn is visible, it's usually the first thing you show to visitors using your telescope; nothing else makes so startling a first impression.

After that first look, though, what can you expect to see? Whether Saturn is a rewarding object for day-to-day study depends largely on how sophisticated your equipment is.

Binoculars and Small Telescopes

When Galileo first studied Saturn with his modest instruments, he concluded that the planet had two nearby moons — which others later drew as doorknob shaped protrusions on either side of the planet.

It's not hard to see how they got this impression, if you view Saturn through a pair of binoculars. You can't actually determine that the planet is surrounded by a flat ring, but you can easily tell there's something unusual about the shape.

Even a small telescope such as a 60mm refractor will reveal the true shape of Saturn's rings. With this size telescope you should also be able to spot Titan, Saturn's largest moon, even through light polluted city skies.

3" to 4-1/4" Telescopes

Saturn begins to reveal some detail in telescopes of this aperture range. Under good seeing conditions, even a three inch will show that the ribbon of light around the planet is made up of more than one ring.

Though the rings look solid enough in a telescope, scientists have found that they are actually a swarm of millions of small bodies (probably fist sized) orbiting Saturn in a single plane. For some reason — most likely a gravitational effect from Saturn's moons — these bodies are absent at certain distances from the planet. So, you see dark gaps that make the feature a series of concentric rings rather than a single one.

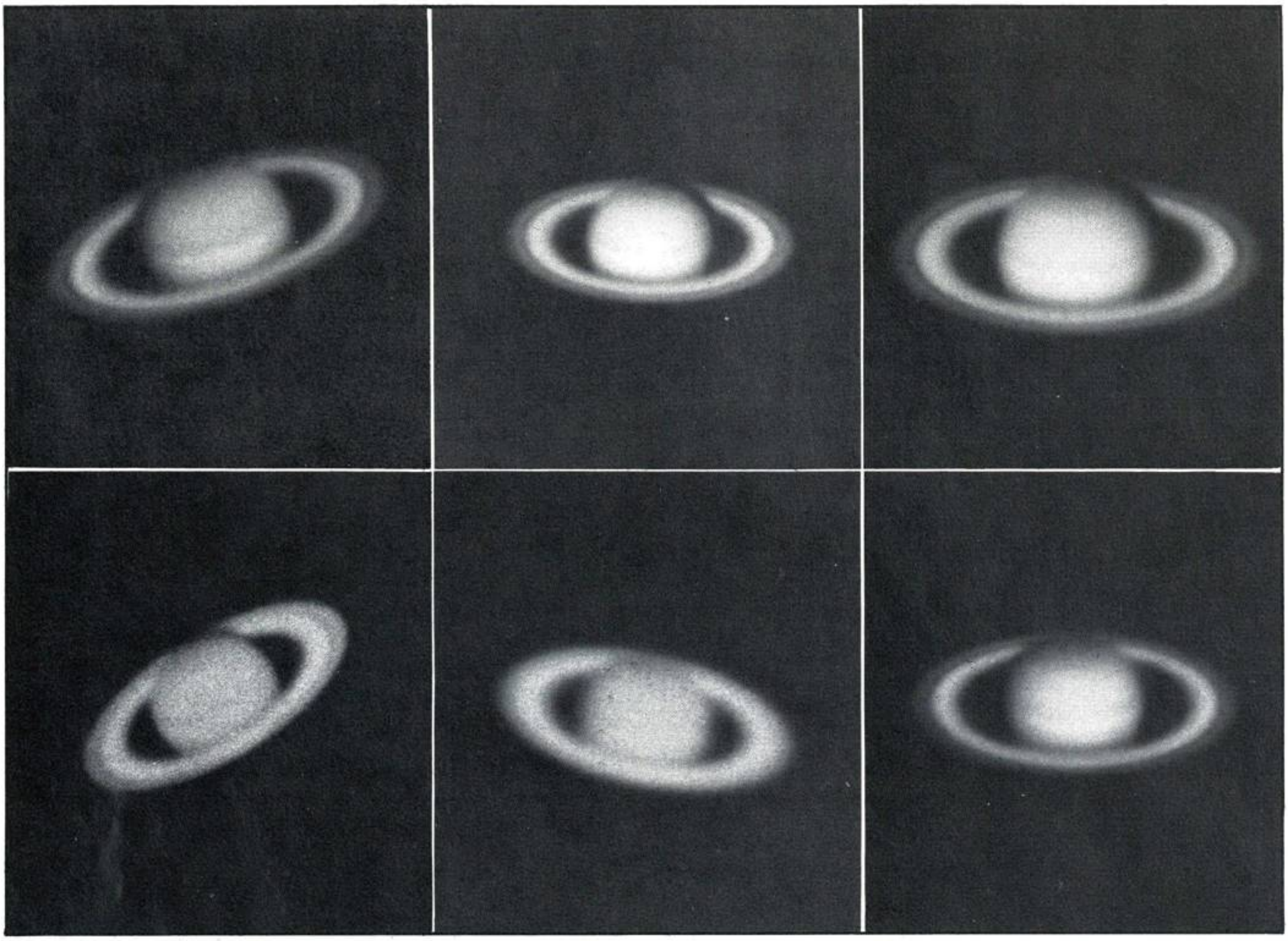
The most prominent gap, by far, is Cassini's division — named after the man who discovered it in 1675. In a small telescope it appears as a thin black thread about 3/4 of the way from the inside of the rings to the outside — which can give you a feeling for how far away Saturn is. That tiny gap is over 3,000 miles wide — more than the distance from New York to San Francisco.

Although a three or four inch telescope will show you this most prominent ring feature (and one or two more satellites as well), we have to step up

SATURN'S SATELLITES

Name	Magnitude	Orbital (Days	Period Hours)	Distance From Saturn (Miles)	Diameter (Miles)	Albedo
Janus	14.0	0	18.0	100,000	230*	**
Mimas	12.1	0	22.6	116,000	560*	0.49
Enceladus	11.8	1	8.9	148,000	342	0.54
Tethys	10.3	1	21.3	183,000	746	0.84
Dione	10.4	2	17.7	235,000	509	0.94
Rhea	9.8	4	12.5	327,000	808	0.82
Titan	8.4	15	23.3	759,000	3,014	0.21
Hyperion	14.2	21	7.6	920,000	220*	**
Iapetus	10 to 12	79	22.1	2,213,000	715	**
Phoebe	16.5	523	15.6	8,053,000	160*	**

*uncertain **not known



The top row shows three photographs by Leo Henzl taken with a Celestron 14. The leftmost is a seven second exposure at f/70 taken on H & W Control Film. The other two were taken at f/90, also for seven seconds, on Kodak SO-410 film. On the second row, the picture at extreme left was taken through a 12-1/2 inch at f/90; Tri-X was exposed for one second. The center one, a six second exposure on Tri-X, was taken with a Celestron 8 using a 12mm Kellner eyepiece. The last is from a home built eight inch f/7 reflector; eyepiece projection with a 7mm eyepiece was used, giving an effective focal ratio of f/80. It was a seven second exposure on Kodak SO-410. On the opposite page is probably the best color photograph of Saturn. Taken with a 61 inch telescope stopped down to 40 inches, it is a composite of 16 images (chosen from over 1,000) taken on March 10, 1974, with Kodak Ektachrome EF film. Top row: Photographs by Leo Henzl Jr. Bottom row (left to right): Photograph by Mike Pierce; Photograph by Roy Belfield; Photograph by James K. Rouse. Opposite: Lunar and Planetary Laboratory photograph.

to medium sized scopes to see any markings on the planet itself.

6" to 8" Telescopes

Compared to the spectacular cloud belts and spots in the atmosphere of Jupiter, Saturn is a washout. While its atmosphere is probably similar in composition to Jupiter's, the ringed planet is cooler and accordingly shows less activity.

With a six inch telescope (or a really fine four or five inch refractor) you might see a belt or two, and you can tell that the equatorial region is definitely whitish in contrast to the relatively dark poles. With an eight inch, you might glimpse some detail in the belts.

Spots, usually white in color, are observed so rarely on Saturn's globe that they are named after their discoverers — the way comets are. The most recent one appeared in 1960 (Botham's spot) and only lasted a month or so.

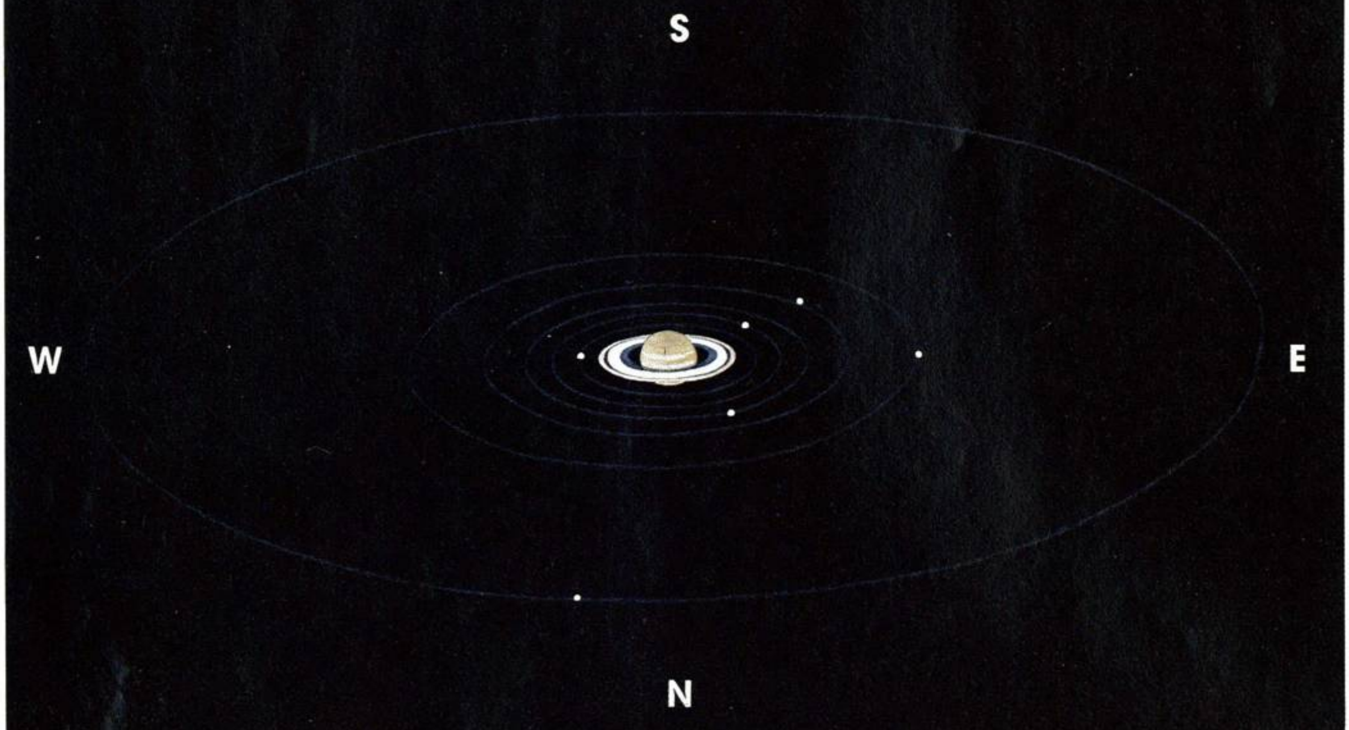
Saturn's rings are labeled "A", "B" and "C", from the outside in. Near the middle of ring A is a fairly prominent gap called Encke's division, which you should be able to observe in a six inch scope under good seeing conditions. Other ring divisions are almost impossible to resolve even with an eight inch.

An eight inch telescope (possibly smaller if seeing is excellent) should reveal Saturn's Crepe ring (C), a faint dusky band on the inside edge of the ring system.

The Crepe ring was first seen with a 15 inch refractor in 1850. You should find it easy to locate with an eight inch telescope once you know what you're looking for. Even with less-than-perfect observing conditions, you can see it as a slight darkening where the rings pass in front of the planet's disk.

Under good conditions you might see five of Saturn's satellites with an eight inch (four with a six inch). One of the most charming of telescopic sights is the appearance of Saturn and its moons in

LOCATING SATURN'S MOONS



Date	Time (EST)	Satellite	Date	Time (EST)	Satellite
Jan. 1	6:00 a.m.	Iapetus(W)	Jan. 17	6:00 a.m.	Tethys
1	8:20 p.m.	Titan	17	3:10 a.m.	Dione
2	3:40 a.m.	Tethys	17	12:40 a.m.	Titan
4	12:50 a.m.	Tethys	17	6:10 p.m.	Rhea
4	5:10 a.m.	Rhea	19	3:10 a.m.	Tethys
5	10:10 p.m.	Tethys	19	8:50 p.m.	Dione
6	4:40 a.m.	Dione	21	12:30 a.m.	Tethys
7	7:30 p.m.	Tethys	22	9:50 p.m.	Tethys
8	5:30 p.m.	Rhea	24	7:10 p.m.	Tethys
8	10:10 p.m.	Dione	24	9:40 p.m.	Titan(W)
9	12:20 a.m.	Titan (W)	26	6:40 p.m.	Rhea
13	12:50 a.m.	Rhea	28	1:40 a.m.	Dione
			30	7:20 p.m.	Dione

In a telescope, Saturn's brightest moons are most easily seen when they are farthest left or right of the planet's disk. Above is a table of the greatest eastern elongations of Saturn's most prominent moons. Western elongations (marked "W") are given for the two moons with the longest orbital periods, while dates for the other moons are eastern elongations. The orbits of Saturn's six brightest satellites are shown above. The two outermost are easy to see in a small instrument, but to catch all six requires a 10 inch telescope. The diagram presents Saturn as you would see it in a normal, inverted image astronomical telescope: South is at the top and east is at the right. For instance, Rhea is pictured here at greatest eastern elongation.

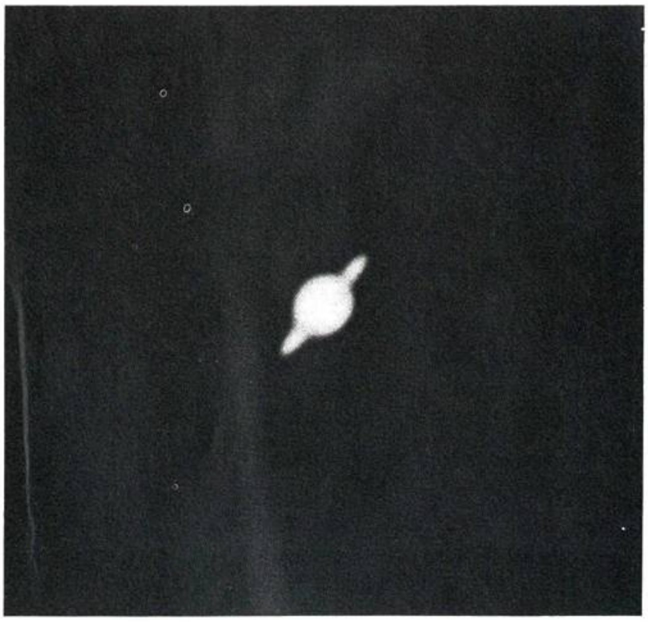
a medium sized RFT (richest field telescope, about f/4). At 30 power or a little less with an eight inch — especially early in the evening, when there is still a trace of blue in the sky to contrast with Saturn's yellow — Saturn and its rings appear in brilliant miniature, surrounded by a retinue of satellites.

Large Instruments

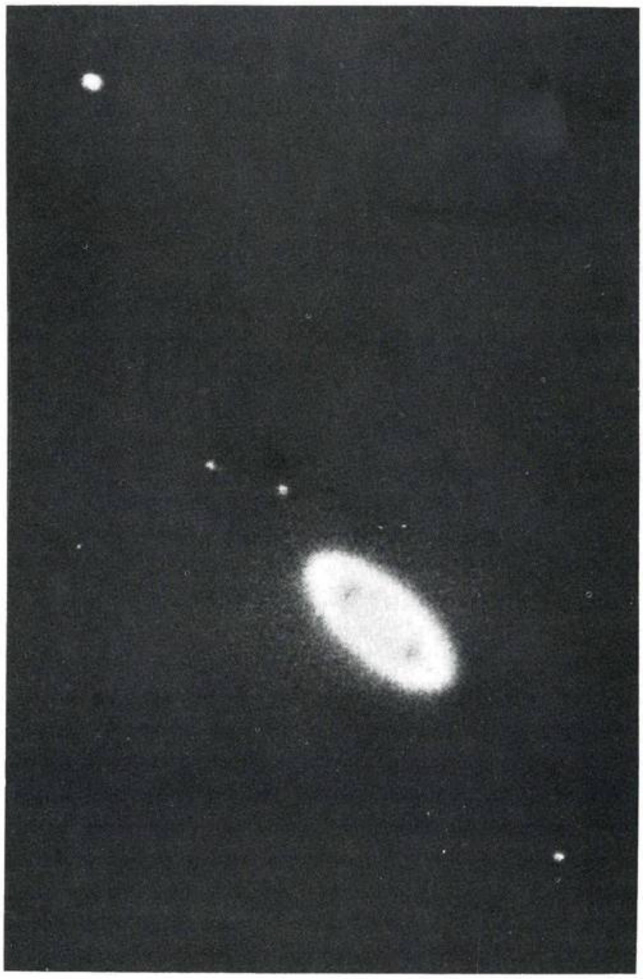
With a 10 or 12 inch telescope you can see semipermanent markings and other details in Saturn's atmosphere. Low surface brightness may account for why Saturn takes high magnification better than any other planet. On a good night you can use magnification up to 50 power per telescope inch of aperture — that's 500 power for a 10 inch instrument.

Of Saturn's 10 moons, 8 can be seen by careful observers with a 12 inch telescope (6 with a 10 inch). The other two are photographic objects.

Saturn reaches opposition Jan. 20 this year, so it will be a good month for viewing the ringed planet's satellites and cloud surface detail. Near opposition the moons appear about 1/2 magnitude brighter than they do when Saturn is farthest from Earth. But unfortunately, on the day of opposition, Saturn is close to the nearly full moon, so background light will obscure the fainter satellites. To help you locate Saturn's moons, consult the table accompanying this article. On these dates Titan, Rhea, Tethys, Dione, and Iapetus will be at greatest eastern and western elongation (farthest to the left or right of the planet).



This long exposure of Saturn with its rings nearly edge-on was taken with a 4-1/4 inch telescope. Eyepiece projection through a one inch Kellner was used for a six second exposure on Tri-X. Photograph by Conrad Kussner.



It takes a relatively long exposure to capture images of Saturn's moons, so detail of the planet itself is washed out. From the top, these are Titan, Dione, Tethys and Rhea. Photograph by F. Zeh.

Iapetus presents an interesting mystery. Evidently one side of the satellite is six times brighter than the other. When its orbit takes it to the west side of Saturn, it's 10th magnitude — easily picked up in a three inch telescope. As it moves east, it fades to 12th magnitude.

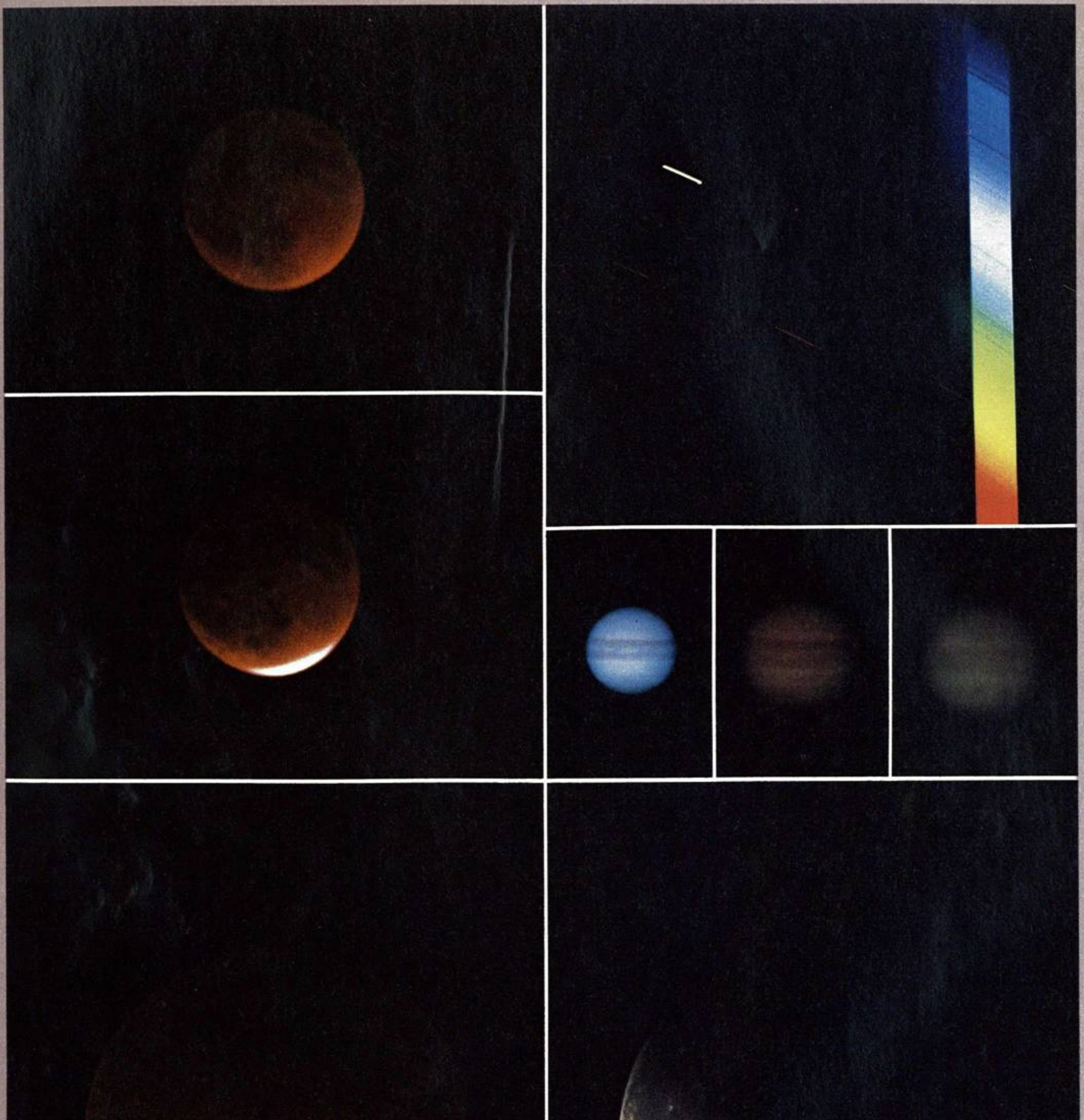
More than half of Saturn's brightness comes from its rings at this opposition. The planet's equator and ring system tilt 26.7 degrees toward the sun. Consequently, we see the rings at a slowly changing angle during its 29-1/2 year journey about the sun.

At two positions, the rings are presented to us edge-on, and disappear completely even in the largest observatory telescope.

The ring system is 172,000 miles in diameter (larger than Jupiter), but is remarkably thin. Some recent research says the thickness may be on the order of just a few feet.

When the rings disappear, Saturn's magnitude drops to +0.9. When they're wide open, the planet can appear as bright as magnitude -0.4. The last time of maximum brightness was the opposition of 1973. Now the rings are closing up again, and will present themselves edge-on in 1980 — the first time since 1966.

Saturn will be well-situated for observing until the middle of July, when it will be close to the sun at dusk.



Comet West Is Coming

by
Richard Dilsizian

Observers can bring in the New Year of 1976 with a cheer for a celestial parade of the planets — and a new comet expected in March's morning skies. Mercury, Mars and Jupiter are all well placed for viewing, and Saturn joins their ranks later in January after it reaches opposition. With all three bright, well-known celestial bodies — Mars, Jupiter and Saturn — having reached opposition within the past three months, this will indeed be a splendid month for planetary viewing and astrophotography.

Comet West (1975n)

Richard M. West of the European Southern Observatory in Geneva reports a new comet that should reach magnitude 5.0 in mid-March. West located the comet (on Aug. 10, 1975) on photographs taken with the observatory's 100cm (39.37 inch) Schmidt telescope at La Silla, Chile.

According to Brian Marsden of the Smithsonian Astrophysical Observatory, there is a chance that comet West will be an impressive object. (Nobody wants a replay of the 1974 Kohoutek disappointment, of course.) But current predictions are that the comet will reach a maximum of 0.5 magnitude when it nears perihelion on Feb. 25. At that time, unfortunately, it's expected to be only 13 or 14 degrees from the sun, and so will be difficult to observe.

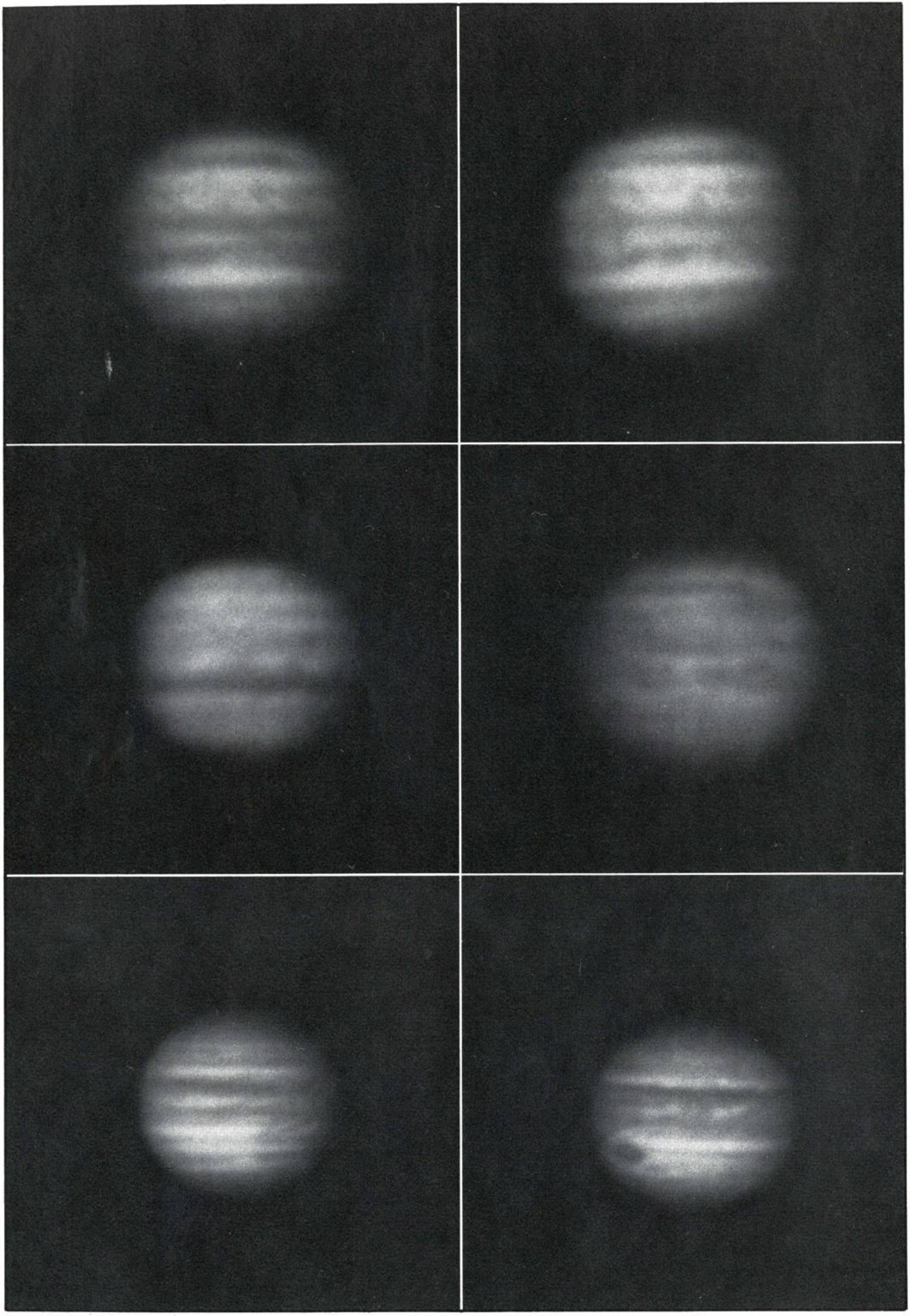
Comet West might be far enough from the sun by March 3 (at about 17 degrees) to be a good sight, though it will have dimmed to 1.6 magnitude. Marsden predicts a magnitude of 4.6 by March 13, when the comet will be about 35 degrees from the sun.

On the opposite page, the two pictures of the Nov. 18, 1975 lunar eclipse (upper and center left) were taken at totality (5:20 p.m. EDT) and slightly after (5:45), with Fujichrome pushed to ASA 200. Exposures were four and three seconds, respectively. The telescope used (from the top of the Empire State building) was a homemade 4-3/8 inch f/4.6 refractor, at prime focus (500mm) with a 35mm SLR camera. The pair of eclipse pictures at the bottom were taken with a six inch f/8 Criterion Dynascope at prime focus, with a Nikkormat camera body. The film was High Speed Ektachrome, pushed to 400 ASA. The photo (bottom left) showing the umbra-hidden part of the moon was exposed for five seconds. The photo on the right was exposed for 1/500 second. Jupiter has provided interesting viewing and photographic opportunities this season; information about the Jupiter photos on the opposite page is detailed in this month's Sky Almanac. Upper and center left: Photographs by Don Tremino. Bottom left and right: Photographs by Edward C. Kishkill. Right center (from left to right): Photograph by Steve Greco; Photograph by Steve Corsi; Photograph by John Sanford. Upper right: Photograph by J. Patterson.

JOVIAN SATELLITE OCCULTATIONS AND TRANSITS

Date	Satellite	Type	Times (EST) begin	Times (EST) end
Jan. 4	2	Oc	11:17 p.m.	1:01 a.m.
6	2	Sh	8:57 p.m.	11:29 p.m.
6	1	Oc	9:55 p.m.	1:26 a.m.
13	2	Sh	11:33 p.m.	2:05 a.m.
13	1	Oc	11:50 p.m.	3:21 a.m.
14	1	Tr	9:03 p.m.	11:15 p.m.
14	1	Sh	10:23 p.m.	12:34 a.m.
20	2	Tr	11:32 p.m.	2:09 a.m.
21	1	Tr	11:00 p.m.	1:12 a.m.
27	3	Oc	11:21 p.m.	2:04 a.m.
29	1	Oc	10:15 p.m.	1:41 a.m.

"Tr" = transit of satellite   "Sh"=transit of satellite shadow



Though much fainter by then, the comet will rise more than two hours before the sun, presenting itself against a dark sky.

Marsden remarked that early observations from Australia indicate that the comet might turn out to be brighter than originally predicted — but he advises caution.

Even if comet West has no surprises in store for us, a fifth magnitude comet against dark night skies will be an interesting sight even in binoculars and small telescopes. For readers with large telescopes, the predicted positions of comet West for January (as it brightens from magnitude 10.5 to 8.6) are in the box below.

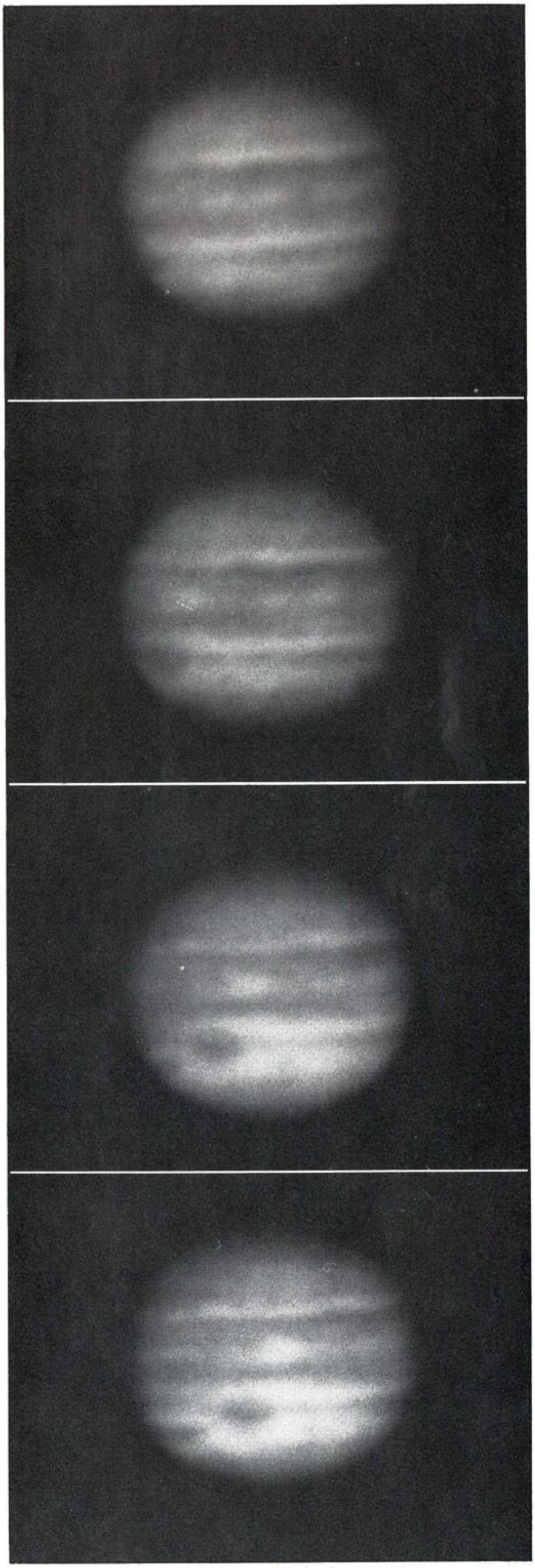
Date	Right Ascension	Declination
Jan. 3	$21^h12.30^m$	-34°45.5'
13	$21^h31.22^m$	-33°05.0'
23	$21^h53.43^m$	-30°55.9'

Mercury

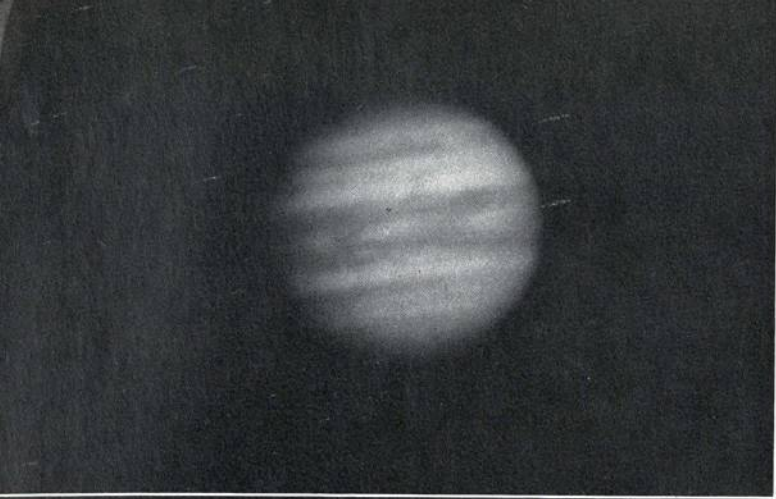
Mercury begins the new year as an evening star displaying an 80 percent illuminated disk with an apparent magnitude of -0.6. Look for the planet in the west right after sunset a day or two before or after Jan. 7. On that date it will reach its greatest separation from the sun in the twilight sky (called greatest eastern elongation). After the 7th, from our Earthbound vantage point, the angle between this swiftly moving planet and the sun will close until Mercury arrives at inferior conjunction on Jan. 23. It will then move into the morning sky — reaching visibility on Jan. 28, when it will display an eight percent illuminated moonlike crescent phase and have a visual magnitude of +1.7.

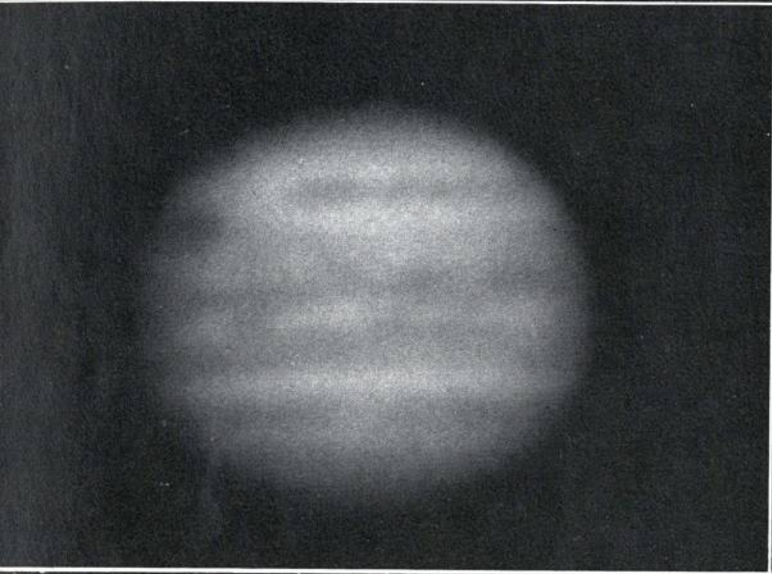
Venus

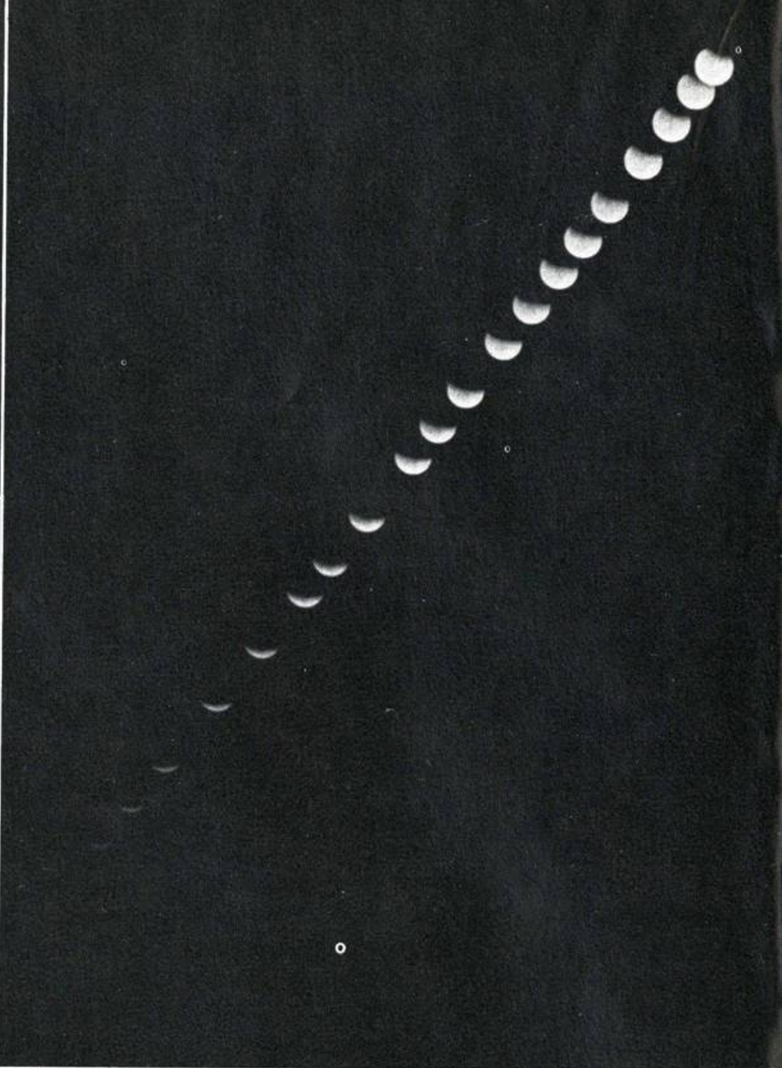
Venus remains a brilliant morning star during January. The cloud shrouded planet shows 3/4 of its lighted surface to us throughout the entire month, and will look like a tiny gibbous moon in a telescope. Its magnitude stays fairly constant at -3.5, or about 7.04 times as luminous as the brightest star, Sirius.



The six Jupiter photographs on the opposite page were all taken with eight inch telescopes. The top pair, taken less than an hour apart on Sept. 14, 1975, shows a clear record of Jupiter's rapid rotation. Shot in conjunction with a 16mm eyepiece and a Celestron 8, they were exposed for 3.5 seconds on H&W Control Film. The same data apply for the middle two photos, except that the right hand one (taken on a night of unusually good seeing) is a three second exposure. They were taken on Oct. 25 and Nov. 4, 1975. The bottom pair also used eyepiece projection — a 7mm eyepiece on a home built eight inch f/7 Newtonian. Both were exposed for seven seconds on High Contrast Copy Film. The four photos at right were also taken with an eight inch, home built f/8 Newtonian. The photographer used eyepiece projection with a 4mm eyepiece, for a two second exposure on Tri-X. Taken about 15 minutes apart on Nov. 1, 1975, they also show Jupiter's rotation. Top four: Photographs by Christopher Bowland. Bottom pair: Photographs by James K. Rouse. Right four: Photographs by Leonard Marek.







Mars

The red planet is still fairly close to Earth — about five light-minutes or 57.5 million miles away — as the New Year begins. Located just east of the prominent V-shaped open star cluster (Hyades in Taurus the bull), Mars shines brilliantly at magnitude -1.1. Mars will appear extremely reddish to the unaided eye — and since it is now past opposition, it displays 98 percent of its disk to us which will decrease until the planet has a distinct gibbous appearance in a telescope. The beginning of the month is still a favorable time to observe our planetary neighbor because it will display a 15 arc-second disk to us. By month's end, however, its disk will have shrunk perceptably to 11.4 seconds of arc. At magnitude -0.3, the distance between Mars and Earth increases to 76,446,000 miles. Mars passes five degrees north of the moon on the 14th.

Jupiter

The largest planet is increasing its distance from us this month, so its magnitude decreases as well; it is -2.1 on Jan. 1 and -1.9 by the month's end. The equatorial and polar diameter of the Jovian behemoth undergo similar decreases in size. Jupiter's equator shrinks from 42 seconds of arc to 38 seconds, and the polar diameter from 39 to 35 seconds. The planet's distance from Earth increases by 47,000,000 miles during January — to 485,683,000 miles away by month's end. At these huge distances, it takes light over 40 minutes to reach us on Earth — at 186,000 miles per second!

At sunset, Jupiter will be close to transit — reaching the meridian at 6:20 p.m. at the beginning of the month, and at 4:30 p.m. in late January. In the constellation Pisces all month, Jupiter will pass four degrees south of the moon on the evening of Jan. 9.

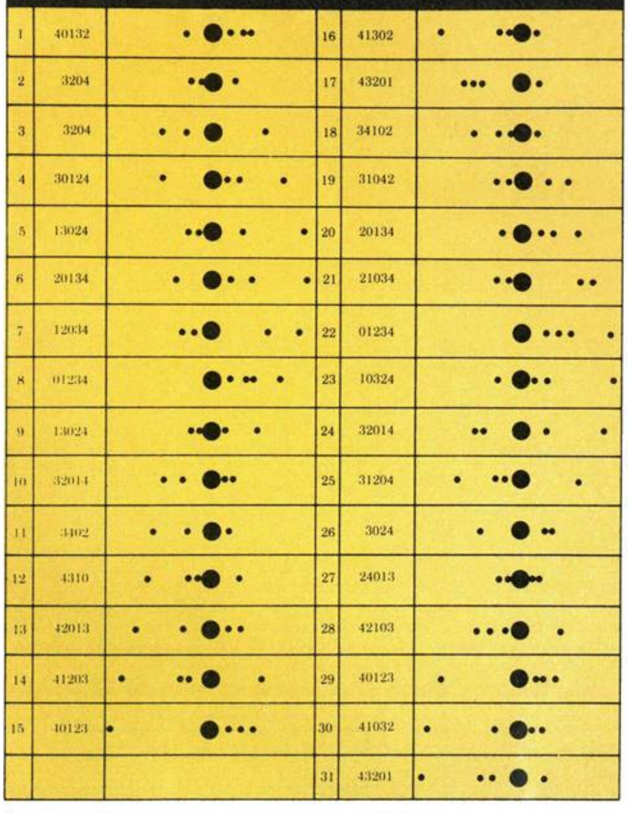
Readers have sent in many interesting photographs of Jupiter — both color and black and white.

Especially interesting is the Jovian spectrum on page 38 by Joe Patterson. He took this very simply — by fastening a diffraction grating to a 35mm camera equipped with a telephoto lens (Spiratone) of 135mm focal length. The camera was focused on Jupiter and left unguided for a two minute exposure at f/2.8. As the image trailed across the GAF 500 film, it left a brilliant spectrum.

The two Jupiter photos in the upper left were taken by eyepiece projection. The top one was with a homemade 12 inch f/15 Cassegrain; the image was projected through a 10 power microscope objective, giving an effective focal ratio of f/150. The data for the other photos are identical to those cited for the Marek pictures on the preceding page. The photo at top right of the emerging lunar eclipse on Nov.18, 1975 is a series of one second exposures taken five minutes apart, with Tri-X film at f/8. The bottom picture is an overexposed image of the planet Mars as it passed near the star cluster M-35 (the smaller cluster to the right and below is NGC-2158). In this 15 minute exposure with a home built six inch f/5 Newtonian (stopped down to f/6), a Nikon F was used with Kodak 103a0. Top left: Photograph by Ron Price. Center left: Photograph by Leonard Marek. Top right: Photograph by Lewis Miner. Bottom: Photograph by Robert Provin.

JANUARY SATELLITES OF JUPITER

9:30 p.m. EST, 6:30 p.m. PST



1	40132	16	41302
2	3204	17	43201
3	3204	18	34102
4	30124	19	31042
5	13024	20	20134
6	20134	21	21034
7	12034	22	01234
8	01234	23	10324
9	13024	24	32014
10	32014	25	31204
11	3402	26	3024
12	4310	27	24013
13	42013	28	42103
14	41203	29	40123
15	40123	30	41032
		31	43201

Jupiter's four largest moons are so bright you can see them easily in even the smallest telescope. Orbiting swiftly around Jupiter in 2 to 17 days, their positions as viewed in a telescope change from night to night. Sometimes, especially when two moons are close to each other, their motions become evident with only a few minutes' observation. Eastern and Pacific Times are provided; subract one hour for Central Time, and add one hour for Mountain Time. First column (left) gives dates; second, the moons relative to Jupiter (1=Io, 2=Europa, 3=Ganymede, 4=Callisto, 0=Jupiter's disk); third, the approximate positions of the moons as seen in an "inverted image".

The other three Jupiter pictures in the middle of the page were taken with a variety of instruments. The one farthest left by Steve Greco was taken with an eight inch Cave Newtonian using eyepiece projection with an 8mm eyepiece; the exposure was three seconds on Kodak 64. The one in the center by Steve Corsi was a two second exposure on a Cave six inch f/8 scope; effective focal length was 1,440 inches. The third photo (by John Sanford) employed a 12 inch f/10 projected through a 16.3mm eyepiece and exposed for 4/5 second on Fujichrome R-100.

Data for the black and white photographs are given in the captions on pages 41 and 43. The middle two pictures on page 40, taken by Christopher Bowland on the same night with the same equipment, show what a difference the steadiness of the air can make. Not how much more belt detail shows in the left hand picture (the difference is even greater, of course, on the original negative).

Saturn

For information on observing Saturn, see this month's Gazer's Gazette.

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by

Terence Dickinson

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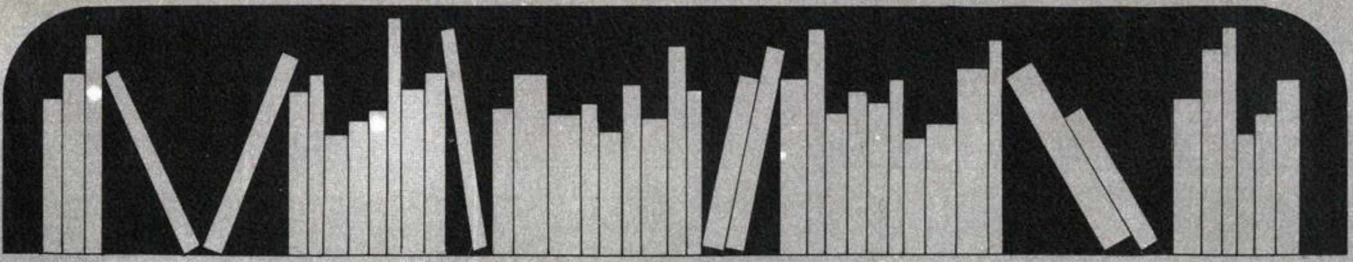

Ufology: New Insights from Science and Common Sense

by JAMES M. McCAMPBELL

153 pages, hardcover, $10.00*
Jaymac Co. (1974)

This first-rate treatise by a leading nuclear and space engineering administrator freshens the air surrounding the complex and often bewildering manifestations of the unidentified flying objects phenomenon. Appearing in the wake of J. Allen Hynek's **The UFO Experience** (see Astronomy Reviews, December 1974), McCampbell's work focuses long overdue scientific attention on this potentially important fringe area of human knowledge.

The table of contents reads like a science or engineering textbook, unlike its forefunners about UFOs. Pertinent quotations by noted persons head each of the 10 chapters.

While the total remains unknown, the author estimates that the number of UFO sightings worldwide is on the order of 500,000. Out of apparent chaos and lack of data in such reports, McCampbell brings order and convincingly shows that vast new knowledge is being overlooked by scientists who disclaim the phenomenon.

This new knowledge rises from reported variations of luminosity, color and sound in numerous close encounters reported from around the globe. The sequences indicate a logical cause and effect relationship, opening insight into possible propulsion mechanisms. Even the scoffed-at descriptions of UFO occupants are shown to contain valuable information.

As a working hypothesis, McCampbell assumes that "UFOs are mechanical constructions that appear and behave in general accord with accounts of the witnesses." While most ufologists seem convinced that UFOs represent far more than just "nuts and bolts" spacecraft, the author's assumption appears to have merit as shown by the new insights resulting from it. By accepting sighting reports at face value, investigators are thus free to direct their efforts away from establishing witness credibility and toward exploration of the actual sighting data itself.

Together, the books by Hynek and McCampbell form an important turning point in the history of the UFO phenomenon. **Ufology** delivers what it promises, and in an impressive manner. *James Mullaney*

* *Also available in paperback for $3.95.*

Artificial Satellite Observing and Its Applications

by HOWARD MILES

216 pages (illus.), hardcover, $15.75
American Elsevier Publishing Co., Inc. (1974)

Artificial Satellite Observing and Its Applications is an A to Z treatment of satellite observing.

In the first chapter, Patrick Moore, popular British astronomy author, offers a very authoritative history of United States and Russian space programs. For readers who might be too young to remember, Moore communicates well the frustration experienced by struggling American space scientists as try after try failed — with Sputnik beeping merrily overhead! Those who remember the genesis of space exploration will enjoy this well-written retrospective.

The only real disappointment in this book is that Patrick Moore's chapter is too short.

Geoffrey Falworth, assistant to the director of the Artificial Satellite Section of the British Astronomical Association, gives a thorough account of the building and launching of satellites. Actual accounts of launch preparations show the overwhelming amount of work that goes into an unmanned flight.

Other chapters deal with everything from behavior of satellites to how to make calculations for accurate prediction of satellite passages. The chapter dealing with radio tracking includes transmission frequencies of satellites still broadcasting.

The book is richly illustrated and full of diagrams, formulas and tables. Some of it requires a fair amount of mathematics, but the reward of watching an object appear at the predicted time makes it worth the effort.

For the astronomy enthusiast who enjoys a challenge, this book is highly recommended. *James C. Baize.*

UFOs Explained

by PHILIP J. KLASS

369 pages (illus.), hardcover, $8.95
Random House (1974)

The casual reader of **UFOs Explained** could easily conclude that Philip Klass is a combination of Albert Einstein, Sigmund Freud and Sherlock Holmes. Knowledgeable readers will say that at best the book is pseudoscience. This is not surprising since Klass' earlier debunking (**UFOs Identified**) was equally unscientific. In **UFOs Identified**, Klass focused on various plasma phenomena similar to ball lightning — but without any grasp of the physics involved in plasmas. Some of the same sightings discussed in **UFOs Identified** are reexplained differently in this book.

A professional writer, Klass is not now and has never been a scientist. The book does read well, though the tools used in explaining UFO sightings are not those of science. They include character attacks, selective choice and misrepresentation of facts, innuendo, false logic, positive and negative name calling, guilt by association, and other tools of the propagandist.

The first half of the book belabors the obvious fact that most UFO sightings can be explained as something other than extraterrestrial spaceships. And in almost all the major sightings "explained" in the second half of the book, there has been significant misrepresentation.

Concerning the abduction of Betty and Barney Hill in 1961 (see **The Interrupted Journey** by John G. Fuller), Klass misrepresents the facts of the sighting; he emphasizes Dr. Simon's apparent lack of belief and casually ignores the star map work of Marjorie Fish (see ASTRONOMY, December 1974). He also disregards the United States Air Force radar UFO sighting at the same time and location, the background and reputations of the witnesses, and the fact that Dr. Simon — a highly rated psychiatrist and hypnotist — knew nothing at all about UFOs and the myriad worldwide reports of landed ships complete with creatures.

The 1964 Socorro (N.M.) daytime sighting of an object taking off with a roar by a police officer who had moments before seen two small beings next to it is "explained" as a hoax perpetrated by the policeman in cahoots with the local mayor — who also happened to be president of the bank and the owner of the unimproved landing site. Klass dismisses the supporting story of a mystery witness because he couldn't have seen the object landing and the police officer driving up the mesa at the same time. The fact is that the witness had reported seeing the object land, and *then* the police car driving toward it — *not* simultaneously at all! Klass postulates the purpose of the hoax as the desire to attract tourists — with the mayor and town benefiting from new hotels and restaurants, a newly paved road, etc. No restaurants or hotels were built, and the road wasn't paved. The officer has in no way benefited — and even left the police force.

Klass misrepresents both the facts of the classic radar-visual sighting near Lakenheath, England, and the views of the scientist who wrote up the case for the American Institute of Aeronautics and Astronautics.

Klass mentions my name in his book three times but never mentions that I am a scientist with 14 years of industrial experience in the development of advanced nuclear and space systems. He details the "great" backgrounds of his experts. He describes Dr. J. Allen Hynek's "Center For UFO Studies" as a one man operation — ignoring the active participation of scientists from major universities in the U.S. and overseas, and the fact that 300 Mutual UFO Network investigators supply data to the center.

If space were available I could easily use 10,000 words debunking the debunker's pseudoscience. As a scientist myself, I would have to give Klass an A for effort and flunk him for his distortions of fact, his failure to tell the whole truth and nothing but the truth, and his lack of understanding of human nature. To summarize, Klass dismissed. *Stanton T. Friedman.*

GREENWICH OBSERVATORY*

Vol. 1: Origins and Early History (1675-1835)
by ERIC G. FORBES
204 pages, hardcover

Vol. 2: Recent History (1836-1975)
by A.J. MEADOWS
135 pages, hardcover

Vol. 3: The Buildings and Instruments
by DEREK HOWSE
178 pages, hardcover

When Astronomer Royal Edmund Halley gave the name Cor Caroli to the brightest star in Canes Venatici, he did it in grateful homage to King Charles II, founder of the renowned Greenwich Observatory. Both the star name and the observatory have had colorful histories, often controversial.

Of the star name, Admiral Smyth wrote in his **Cycle of Celestial Objects**, "But it came to pass that it was named Cor Caroli... after a worthless man's heart." And, these three volumes provide a fascinating description of many aspects of the observatory's 300 year history.

Despite this work having three authors, there is little duplication of details. The volumes differ considerably in style and approach.

The first volume opens on a technical level, discussing various complexities and uncertainties in celestial observations prior to 1675 which led to English concern with problems of importance to navigation — particularly the measurement of longitude. Therefore, John Flamsteed was appointed Astronomer Royal by the king to redetermine stellar coordinates by observation. Flamsteed needed proper instruments and an observatory to house them in, so the king authorized construction of the Royal Observatory.

Most of this volume deals with the work of Flamsteed and subsequent Astronomers Royal rather than the design and construction of the observatory. Technical data on Flamsteed's instruments and methods of observation are described at great length (sometimes mathematically) to illustrate the intricacies of his task. Details concerning the arguments between Newton and Flamsteed pertaining to publication of the latter's great atlas and Newton's lunar theory are candidly evaluated as being detrimental to Flamsteed's observing program. The Astronomer Royal's arguments are adequately presented — a change from the usual adulation afforded Newton.

Edmund Halley, the second Astronomer Royal, had been involved in these bickerings, but the volume makes it clear that the observatory made great strides — particularly in the field of positional astronomy — during his term. His successor, James Bradley, inherited its growing tradition of increasing accuracy in observations.

The English author of this volume devotes considerable space to the work of other astronomers, many of them foreign, to show that the labors of Greenwich Observatory were not unique in this field — making the book a valuable source of information about the astronomical world of the 18th century. The leisurely scope of the volume also allows room for interesting anecdotal information.

The volume closes with an account of John Pond's difficulties as sixth Astronomer Royal. Without glossing over blemishes, the observatory is candidly described as having degenerated into a state of inefficiency by the time Pond was harassed into retirement in 1835.

The second volume is written for a more general audience. There are no geometrical diagrams or mathematical equations. But the emphasis is still on the work and character of the astronomers at the observatory. George Airy, seventh Astronomer Royal, is depicted in many of his controversial aspects — from the scorn with which he regarded the actual process of astronomical observation, to his tardiness to recognize the Neptune computation predictions of J. C. Adams.

In the 19th century, the work and the publication of the results of observations were performed with exemplary efficiency. The book makes it evident that this was so — not just as a result of a long established institution, but because of the human traits of the individuals involved. The faults, virtues, mistakes and triumphs of Airy, Christie and their assistants are highlighted.

Positional astronomy, longitude and time were still the paramount concerns of the observatory, so much of the volume deals with those aspects of the work at Greenwich. Another chapter tells how astrophysics and geophysics officially became a part of it. The book concludes with a frank analysis of the present status of the Royal Observatory.

In the third volume, readers are given a guided tour through the Royal Observatory at Greenwich — a tour through time as well as space. This method is appropriate since the old Royal Observatory is now literally a museum of Astronomy and Time; the old observatory buildings in Greenwich Park are now part of the National Maritime Museum. Unfortunately, the treatment accorded Greenwich has not been granted to Herstmonceux in this volume. The castle there goes back in time too, and it has a fascinating history. But hardly any of it is mentioned in these three books.

We are first guided through the Greenwich buildings in a chapter devoted to their construction and the room-to-room changes made during the terms of each Astronomer Royal. That done, we pass through again — this time inspecting the instruments, noting salient points of their histories and use. The volume does this in a classified order: First the mural instruments are surveyed, then the transits, zenith telescopes, equatorials, magnetic devices, meteorological instruments and astronomical clocks.

As in walking through a museum, we are confronted here with many names and dates (primarily of statistical value). Nevertheless, the text is liberally sprinkled with interesting facts and stories making for lively reading.

As in the other volumes, there are illustrations depicting some of the objects and people mentioned. With its readability, candor, accuracy and thoroughness, this work should serve as a model for any institution publishing its history. *Donald F. Trombino.*

* *All three volumes were published in 1975 by Taylor & Francis (London). The set is available domestically for $60.00 from Charles Scribner's Sons.*

◆

Galactic and Extragalactic Radio Astronomy

edited by GERRIT L. VERSCHUUR & KENNETH I. KELLERMANN

402 pages (illus.), hardcover, $40.10
Springer-Verlag (1974)

Near the turn of the century, Charles Nordmann, a graduate student at the University of Paris, had an idea for an experiment.

"Nordmann carried his apparatus to the top of a high glacier in France, tried to detect the sun with a 175 meter antenna wire on a single day (Sept. 19, 1901), obtained negative results, and did not try the experiment again.... It has been speculated that with more patience his detection apparatus was capable of detecting the stronger bursts of solar radio emission."

This sad tale of a young man too easily discouraged is related at the beginning of a chapter on radio stars. Fortunately — although 30 years elapsed in the interim — the curiosity and persistence of Karl Jansky of Bell Laboratories launched the field of radio astronomy.

In the 40 years since Jansky's discoveries, radio astronomy has developed into a vastly productive research effort. The sophistication of contemporary methods has opened a gap between modern textbooks and research literature. Intending to fill this gap for those aspiring to in-depth understanding of current radio research outside the solar system, 12 staff members of the National Radio Astronomy Observatory at Green Bank, W. Va. have produced this remarkable book.

Each chapter is written by a single author (in one case, two authors) on his own area of active research — thus reflecting enthusiasm not usually found in the absence of personal commitment. The chapters are largely independent — each of interest in its own right.

Contributions on the galaxy include discussions of supernova remnants, pulsars, nonthermal emission, neutral hydrogen, HII regions, radio stars, magnetic fields and interstellar molecules. The extragalactic topics are quasars, radio galaxies and neutral hydrogen. Though little space is devoted to instrumentation, there is a welcome chapter on interferometry and aperture synthesis.

The qualitative sections are stimulating; portions can be understood and enjoyed by anyone with a modest astronomy background.

The quantitative sections are another matter. Understanding these requires a knowledge of graduate-level physics. In the words of the editors, the book is aimed at "graduate students and interested workers in other fields."

One might take issue with the claim for the latter category. Although the notation is conventional, the unfamiliar reader soon finds himself confronted with a host of undefined parameters and terms peculiar to the radio astronomy discipline. The problem is particularly noted in the first chapter where little effort is made to acquaint the uninitiated with definitions of terms such as brightness temperature, intensity, flux and integrated emission. Simply providing the units of these quantities would be helpful, but units are lacking in the text and on the illustrations.

Typographical errors in familiar equations are obvious but they shake one's confidence in unfamiliar equations with which the reader may be experiencing difficulty. Examples are found in equation 1.2 which contains two errors, and after the next equation where we find an incorrect definition of the relativistic "Gamma". (Further confusion may result on the following page where the same symbol is used for the spectral index.) The slope of the cosmic ray electron spectrum is too large by an order of magnitude in equation 1.23, and one may wonder what a "temperature versus temperature" plot is on page 12. (It should be temperature versus frequency.) These and other errors are perhaps a bit too numerous in the first chapter.

The situation improves markedly in later chapters where somewhat more care seems to have been devoted — particularly to defining terms and symbols as they are introduced. Some parameters used in chapter one can be found defined in subsequent chapters.

No book of this kind can be comprehensive in its review of a subject with such diversity, but the authors have done an extraordinary job of outlining the principal areas of contemporary observation. The style is crisp, the organization straightforward, the illustrations large, clear and well chosen. Excellent lists of references (some are annotated) accompany each chapter.

While presenting the collective results of radio observations, the book does indeed "take over where most textbooks on radio astronomy leave off." It is fitting that an attempt is made to draw these results together in a discussion of the universe as a whole with a final chapter entitled "Cosmology". *Michael Moe.*

◆

Man and Cosmos

edited by JAMES CORNELL and E. NELSON HAYES

192 pages (illus.), hardcover, $8.95
W. W. Norton & Co. (1975)

Amid the plethora of new books and publications relating the exciting discoveries being made by space age exploration of our solar system, this work shines like a supernova.

Subtitled "Nine Guggenheim Lectures on the Solar System", **Man and Cosmos** contains a widely acclaimed series of talks by eminent astronomers and space scientists held in Washington in the fall of 1972 under the sponsorship of the Smithsonian Institution.

While a brief review can hardly do justice to a volume as significant as this one, a look at the individual contributors and their topics will convey some idea of its quality and scope: "History of the Solar System" by A.G. W. Cameron; "The Sun" by Owen Gingerich; "The Moon" by John A. Wood; "The Planets" by Carl Sagan; "Planetary Atmospheres" by S.I.

Rasool; "The Outer Planets" by John S. Lewis; "The Asteroids" by Myron Lecar; "The Comets" by Brian G. Marsden, and "Perspectives: Past, Present and Future" by Fred L. Whipple.

In addition to these, a lively introduction by astronomer Thorton Page updates the text material to May 1974. He states at the outset that the purpose of those who wrote this book is not technological but rather to broaden man's understanding of the cosmos and his relation to it. Anyone reading **Man and Cosmos** will find this goal eloquently met and come away with a feeling for the tempo and excitement of modern solar system research.

Of the many quotable statements in this volume, perhaps the most facinating is that by Fred Whipple on page 177: "Actually the best evidence so far for extraterrestrial life may be the Russian experiment. Their Mars probe landed in the Hellas region and telemetered back information for about 10 to 20 seconds before it mysteriously cut off. Did little green men come out to find it in their garden? Is it now being studied in subterranean chambers of Mars? If you do not think that is a good argument, I must say that it is the best we have so far for extraterrestrial intelligent life."

Man and Cosmos is illustrated with numerous, well chosen photographs, line drawings and diagrams, and contains a brief but good bibliography. It can be enjoyed and understood by the intelligent layman and specialist alike. *James Mullaney.*

◆

New Frontiers in Astronomy

edited by OWEN GINGERICH

369 pages, hardcover, $13.00*
W. H. Freeman & Co. (1975)

Anyone interested in astronomy has got to have a pile of torn out pages from **Scientific American** stashed somewhere around the house. This monthly magazine has the style, approach, illustrations and content perfectly suited to informing the "interested nonspecialist" about the latest developments in all branches of science.

Every five years or so **Scientific American** compiles a collection of articles on astronomy and publishes them in hardcover. Most of the articles in this present collection date from the 1970-75 period, with a few "oldies but goodies" from the 1950s and another dozen or so from the 1960s. Where necessary, editorial comments have pointed out subsequent developments which alter the conclusions of the individual authors.

This is not a textbook on astronomy, but it is probably better for browsing. Each article stands alone (there are almost a dozen versions of the Hertzsprung-Russell diagram infesting the volume like cockroaches), but they reenforce each other and ultimately tie together to give some sort of "big picture". The selection of these articles out of the hundreds available must have been a difficult task, but the editor accomplished it magnificently.

Think of a topic in astronomy and it will probably be included. The 31 articles are grouped into planetary astronomy, the sun, stellar evolution, the Milky Way, galaxies, high energy astrophysics and cosmology. One interesting theme running through many of the sections was the prominent appearance of chemistry as a discipline in astronomy. The chemical differentiation of the solar system, the plethora of interstellar molecules, the birth of stars and the absolute age of the elements of the universe are topics which could just as easily appear in a collection of articles from a chemical journal.

The selection of authors is also excellent. Astronomers and astrophysicists such as Murray, Whipple, Huang, Iben, Bok, Arp, Dyson, Thorne and Gamow report their discoveries and interpretations. Bibliographies of old articles have been updated in the appendix. Many full page color illustrations are included, although most of the "158 with color" advertised illustrations are just two-color graphs. The resulting product will allow you to throw out those old, crumpled, torn out pages and buy this fine selection of bound articles. *James E. Oberg.*

**Also available in paperback for $7.50.*

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Modern Science Dictionary

second, enlarged edition
compiled by A. HECHTLINGER

848 pages, hardcover, $20.00
Franklin Publishing Company, Inc. (1975)

The **Modern Science Dictionary** is a thick book — 848 pages — though not a large one. Its usefulness to the devotee of astronomy is rather limited, unfortunately. It seems strongest in biological sciences, chemistry, geology, and in the names of prominent scientists. There are rather few definitions that have to do with astronomy, though at the front of the book are "addenda" which seem to have a considerably greater percentage of terms from space science. But not even there could the word "quasar" be found, for example.

The definitions tend to be quite brief and very clear; the language of the definitions seems simpler than that of a typical collegiate dictionary. In fact, one of the aims of this book was to have definitions written in very simple language, suitable to high school students and "the average adult". The definitions dealing with astronomy and optics are usually clear, but the reader who is more than an absolute newcomer to astronomy will find the definitions inadequate because of their brevity.

There are illustrations, but unfortunately they are almost useless. Scattered throughout the book are pages of nine illustrations each, but they are not of terms on nearby pages. On the contrary, one page illustrates totally unrelated words from all portions of the alphabet. What's more, the pictures are numbered in horizontal rows, while in the key at the bottom of the page, the numbers go down in columns. The dictionary definitions do not refer the reader to their corresponding illustrations, so that the user of the book does not know if a particular word has an illustration and — if so — on what page to find it.

The pictures themselves are small and not very informative; the drawing is poor and the pictures are inadequately explained by captions or legends.

The reader who is interested primarily in having definitions of terms in astronomy would do better to purchase something more closely matched to his needs. For a bit less money — in fact $5 less — he can get Gilbert E. Satterthwaite's **Encyclopedia of Astronomy** which, in spite of some faults, is likely to be more useful. A still better buy would be Ake Wallenquist's **Dictionary of Astronomical Terms** which is a paperback; it unfortunately is now out-of-print, but a copy might turn up in a used book store. A new one, soon to be published by the University of Chicago Press, is Jeanne Hopkins' **Glossary of Astronomy and Astrophysics.**

For the price of the **Modern Science Dictionary**, readers could buy the Wallenquist book plus a paperback version of the Columbia-Viking Desk Encyclopedia, and a good collegiate dictionary — and he would have a small reference library much better suited to his needs. *Richard Stein.*

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ASTRO-MART

continued from page 32

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FOR SALE — Dakin 2x Barlow; $30.00. University Optics 20mm Erfle; $16.00. 1-1/4" Meade star diagonal; $10.00. Refractor objective (60mm diameter, 800mm f.l.) mounted in threaded metal cell; $15.00. Contact Charles Hovatter, 485 Cole Ave., Akron, OH 44301. Phone (216) 724-8961.

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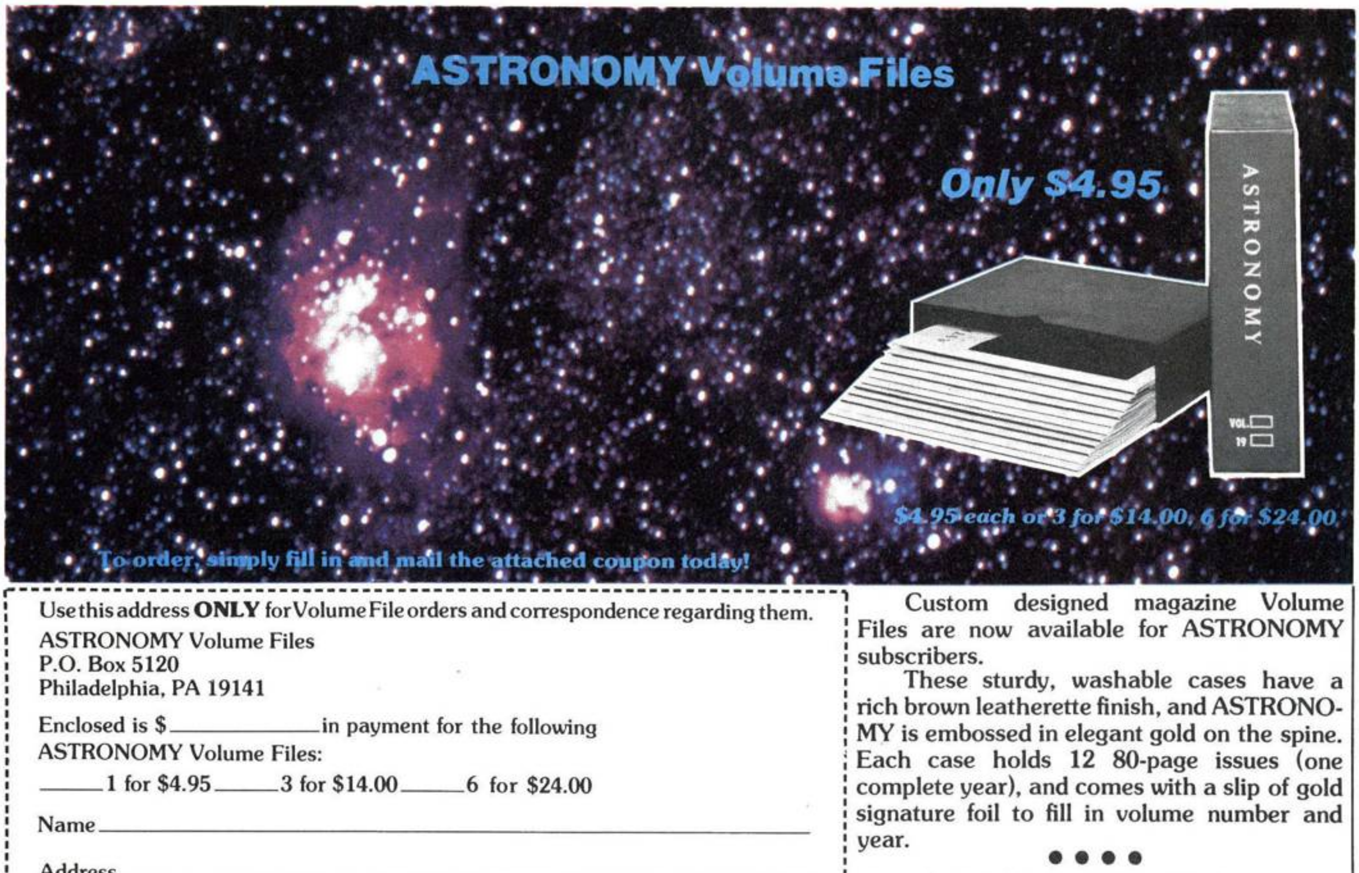
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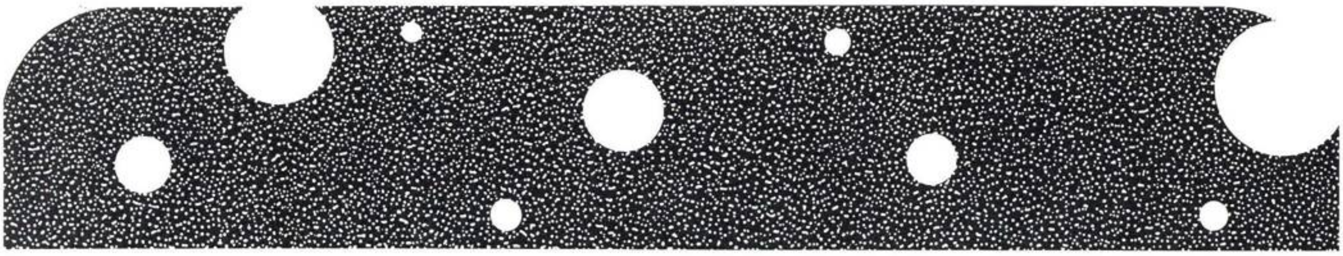


STELLAR FRONTIERS

Stranger Than Quasars

by

Gerrit L. Verschuur

You're alone in the desert at night. Suddenly a light appears, accompanied by an eerie sound.

The light and sound stop abruptly.

Suddenly they reappear — this time brighter and louder. Stop again. Start again. Dimmer, brighter; louder, softer — there is no pattern, only confusion.

The light simply appears in the sky; the sound seems to come from every direction. There is absolutely no way you can tell what's causing it.

Your confusion is the way astronomers feel about one of the newest mysteries of the heavens — the BL Lacerta objects. They are so weird that even quasars seem almost familiar in comparison.

The mystery began 35 years ago (though astronomers didn't know it was a mystery at the time), with a dim variable star in the constellation Lacerta.

Observers' handbooks usually dismiss the constellation Lacerta the lizard with a paragraph — if they mention it at all. It contains one star cluster and the radiant for an unimpressive meteor shower; its brightest star is only fourth magnitude.

Variable stars, though, are where you find them. In 1930 an astronomer routinely catalogued a seemingly unspectacular variable in Lacerta; it was a short-period variable (going from maximum to minimum in a couple of months) which varied from 13th to 14th magnitudes. He tagged it BL Lacerta and moved on to the next one.

But he had only gotten part of the picture, because BL Lacerta doesn't merely vary in brightness from month to month. It also varies from week to week, from day to day, and even hourly on a totally random schedule. To 1930 astronomers, it was a completely unique object; even today, it's a mystery wrapped in an enigma.

From 1930 to 1965, BL Lacerta — just one dim variable among thousands — was virtually ignored. But then a radio telescope sky survey picked it up, and it was recatalogued — VRO 42.22.01 — as a garden-variety radio source, radiating at 610 MHz. The people who ran the survey didn't know that their source was also a variable star; they weren't concerned with cross checking everything optically.

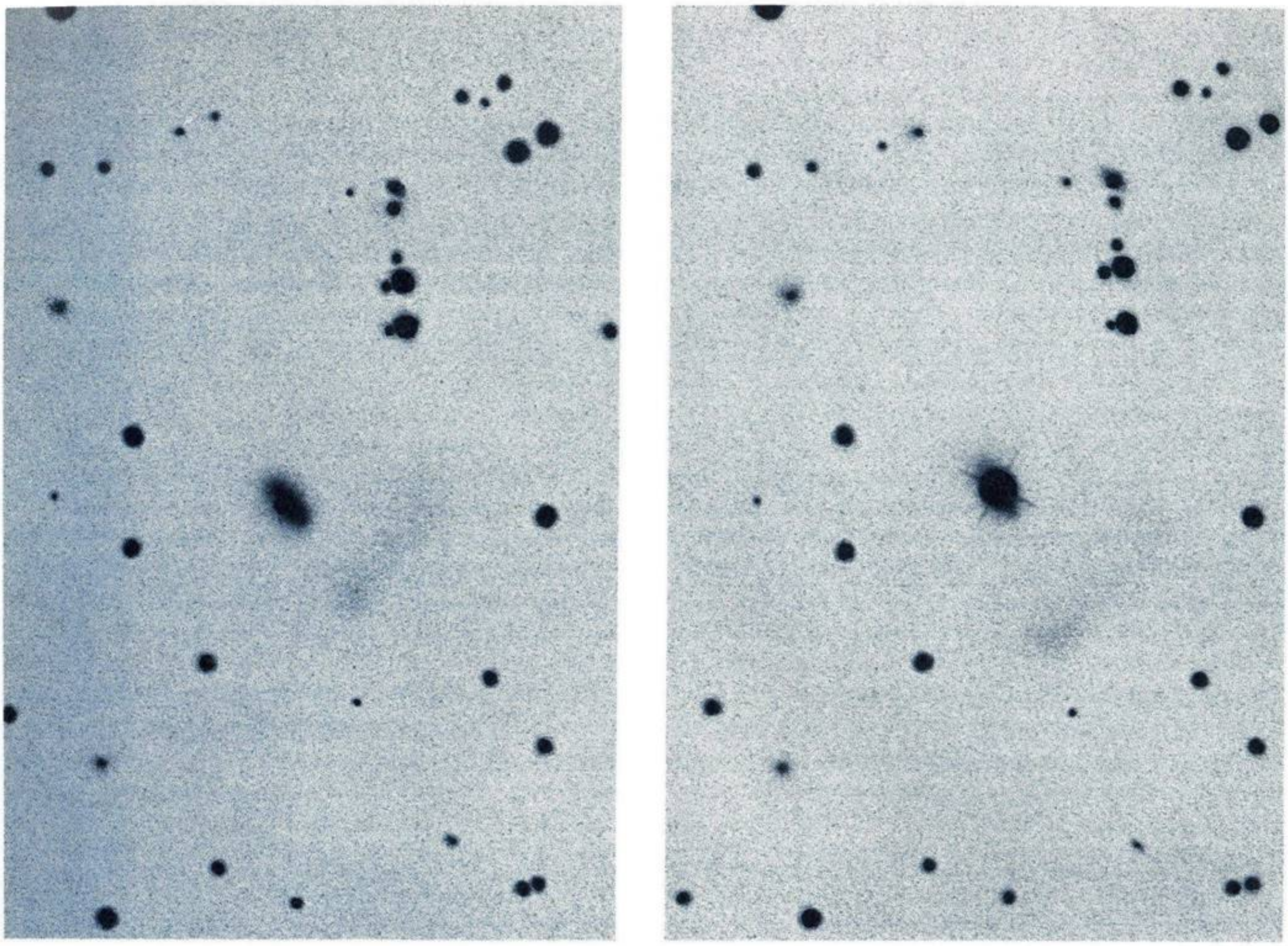
Two other radio astronomers, though, did find something interesting about VRO 42.22.01. They studied its *radio spectrum* (the measure of how the radio brightness of an object depends on the wavelength being monitored), and found that it was emitting an unusual amount of radiation at very short wavelengths — around a few centimeters in length.

This was an exciting discovery because relatively few radio sources act that way. In 1965, this "enhanced emission" at short wavelengths was thought to be characteristic of variable radio sources (much less common than variable stars) — in particular, quasars. So, it was well worth investigating.

They still didn't know that VRO 42.22.01 had been observed and named more than a generation earlier. They did check photographs of that area of the sky, and found a small fuzzy blob in the proper position. It had a bright pointlike center, but didn't

One interpretation of BL Lacerta objects maintains that they are young quasars embedded inside galaxies, undergoing mysterious and dramatic changes in brightness. If this is what they actually are, the young quasar is emitting some 10,000 times as much light as the surrounding galaxy. Painting by Rick Sternbach.

Sternbach



This artist's impression of two negatives of a BL Lacerta object shows how much the brightness can vary over even a short period of time. Light from the bright central object overwhelms the dim nebulosity, even when its brightness is near minimum. Artwork by David G. Lagerman.

look like any known star. And, there was no close resemblance to any known class of galaxies.

The real surprise came when they photographed its spectrum.

Normally, the spectrum of a star or galaxy (or nebula or quasar, for that matter) shows a pattern of light and dark lines — *spectral lines* — that helps us analyze the object. The dark lines appear at wavelengths where energy is being absorbed; the light ones, where energy is being emitted. Elements absorb and emit energy at specific wavelengths, so the pattern of lines allows us to deduce which elements are present in the source.

But in the spectrum of VRO 42.22.01 — alias BL Lacerta — there were *no* spectral lines. This could mean that it is very hot and bright, with its own radiation blotting out the fine details of its spectrum. Or there might be some unknown mechanism at work.

Although BL Lacerta's lack of spectral lines is a fascinating anomaly, it does present a real problem because study of spectral lines makes it possible to tell how far away an object is.

In our expanding universe, the farther away an object is, the faster it is receding from us. If you can measure the speed of recession, you can calculate how far away the object is. It's easy to measure this speed because of a distortion called the *Doppler effect*: Motion away from us causes the spectral lines of a star or galaxy to shift toward the red end of the spectrum. Measure the shift and you'll know the velocity; knowing the velocity, you can compute the distance.

But without any spectral lines, you're lost. BL Lacerta might be a relatively dim, nearby object, or it could be a faraway object that is very bright.

There is a way to get a "ballpark" estimate of how far away an object is — at least to the extent of determining whether it is inside or outside our galaxy. Light that comes from outside our galaxy is modified by clouds of gas and magnetic fields in the Milky Way.

Riverboat gamblers used to employ a technique called the Mississippi Shuffle. It's a way of making a great deal of sound and fury with a deck of cards, without changing the order of the cards at all. When you've arranged the order of the deck beforehand, it's a handy skill to have.

To do the Mississippi Shuffle you grab the deck sideways with your right hand, pinching in with the thumb and fingers so the deck is bent in a shallow U-shape. You put your left hand where you expect the cards to fall, and gently release the pressure; the cards cascade in an impressive waterfall, in a blur too fast for the eye to follow. Everybody has seen this maneuver at least on television, but few realize that it provides a mechanical analogy to the way that light and radio waves move from place to place.

Think of a slow motion picture of these cards moving from the right hand to the left. You have a slow procession of parallel planes, all moving in the same direction.

Light that is 100 percent polarized corresponds to this model. The waves in a ray of light vibrate in certain modes — certain angles with respect to the direction the ray of light is traveling. Most light is not 100 percent polarized, though, and here the analogy with the deck of cards breaks down. If you visualize the cards moving from right to left but not being neatly lined up — instead, having random angles with respect to the direction of travel — then you have a model of completely unpolarized light.

Light doesn't have to be one way or the other, though. Stretching our analogy to the limit, think of a mixture of these two extremes — where some of the cards are oriented in a random way, and others are lined up. This is polarization, which is what we're interested in for BL Lacerta.

Light coming from stars and galaxies can be partially polarized by the clouds of gas and dust in the Milky Way. Radiation picked up in radio wavelengths is also polarized this way. Furthermore, the angle of polarization is rotated when the radiation passes through interstellar magnetic fields. This rotation is different for different wavelengths.

By making observations at various wavelengths, we can deduce roughly how far the radiation has traveled through the Milky Way. The rotation for BL Lacerta is so great that the light has to have originated outside the Milky Way. We can't tell how far away it is with any precision, but we do know it's an extragalactic object.

Finally somebody did look through the old catalogues, and found that VRO 42.22.01 was identical to the "normal" variable star BL Lacerta. Variable it was — but it was neither normal nor a star!

Astronomers immediately began monitoring the brightness of BL Lacerta in all possible wavelengths. It turned out to be rapidly variable at optical wavelengths as well as radio and infrared. The variability seemed to occur on all time scales from hours to days, weeks and even months. In fact, some optical observations suggest that changes in its brightness can occur over mere minutes.

No other object like BL Lacerta was known to exist — so, of course, scientists went hunting. To date they've found about 15 others, all with the oddly featureless spectrum and the rapid, seemingly random, variability. One (OJ 287) even changes color with time. Logically enough, they're called BL Lacerta objects.

In many ways, BL Lacerta objects resemble quasars — but there are definite differences. For instance, quasars do exhibit spectral lines. Also, BL Lacerta objects are much brighter optically than one would expect from their radio intensity if they followed the quasar pattern. This tends to confirm the theory that the lack of spectral lines is the result of BL Lacerta objects being extremely hot and bright.

Although the variability of quasars in radio wavelengths is similar to that of BL Lacerta objects, it seems to be caused by a different mechanism. Quasars expel material explosively, causing a burst of radiation in short wavelengths. As the material — bits of which can be seen in photographs — expands into space, the wavelengths of the radiation increase.

But BL Lacerta objects just have a fuzzy blob of light surrounding them — nothing like a quasar's explosive jets. The key to understanding the objects might well lie in finding out what that faint blob is.

Unfortunately only 1/10,000 of the light from a BL Lacerta object comes from this fuzzy surrounding. So, its faint light is "contaminated" by light from the bright center. Trying to get a spectrum of just the fuzzy part is like trying to identify one face in an aerial photo of the crowd at a football game.

One group of astronomers does claim to have isolated spectral lines from that dim light. Others disagree, though. If the lines they recorded actually do come from that surrounding dimness, then BL Lacerta objects are very far away (but not as far as the typical quasar).

If these objects actually are as far away as they seem to be, then their light variations are such that changes in their brilliance are equivalent to the total light output of a large elliptical galaxy. How you might cajole 100 billion stars into blinking on and off in unison is a mystery.

Perhaps BL Lacerta objects are very young quasars embedded in the center of galaxies, and undergoing some strange and dramatic changes in intensity. If this is so, they might be a clue in unraveling the quasar mystery. But until we do know their distance accurately, we can't draw any really worthwhile conclusions.

Our only hope is to somehow obtain indisputable spectral lines from the faint area surrounding a BL Lacerta object. It might be possible when the brightness of the object is at a minimum — but since variations are random, we have to rely on luck. Also, as more BL Lacerta objects are discovered, we might find one where the surrounding fuzziness is brighter and more extended.

BL Lacerta objects may well be the key to understanding quasars and even radio galaxies, but right now they are only a frustrating mystery. All we can do is search and hope.

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ASTRO-MART

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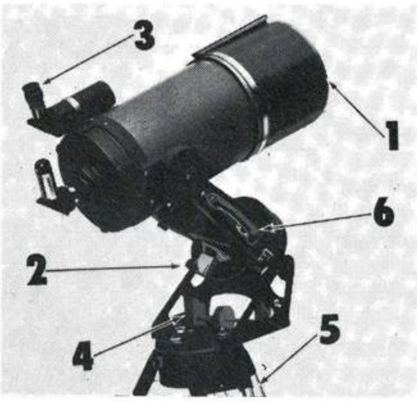

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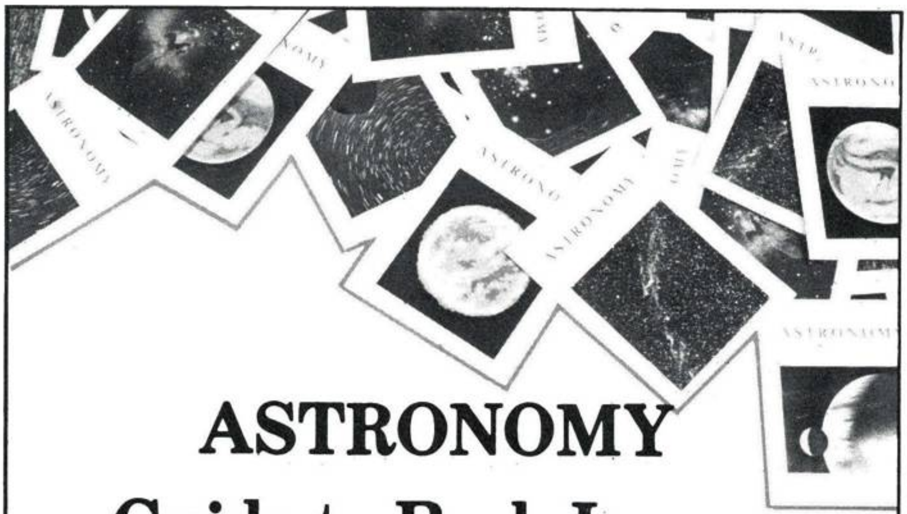

ASTRONOMY

Guide to Back Issues

Reader interest in back issues of ASTRONOMY magazine is higher than ever. As a result, our stock of back issues is swiftly dwindling. The following back issues are depleted: September, October, November, December 1973; January, February, August, December 1974; and April 1975.

Below is a guide to ASTRONOMY back issues that are still available. For your convenience it is updated monthly, and completely revised about every six months. While they last, back issues are available for the cover price of $1.50 each (price includes postage).

When ordering, please clearly state quantity, volume, number, month and year for each issue (first issue was August 1973), and include payment with your request. If issues ordered are no longer available, unless you instruct us to forward a refund or substitute issues, we will automatically extend your subscription appropriately.

Vol. 1, No. 1 - August 1973	**Available**
Vol. 2, No. 3 - March 1974	**Available**
Vol. 2, No. 4 - April 1974	**Short Supply**
Vol. 2, No. 5 - May 1974	**Depleted**
Vol. 2, No. 6 - June 1974	**Short Supply**
Vol. 2, No. 7 - July 1974	**Available**
Vol. 2, No. 9 - September 1974	**Available**
Vol. 2, No. 10 - October 1974	**Available**
Vol. 2, No. 11 - November 1974	**Available**
Vol. 3, No. 1 - January 1975	**Available**
Vol. 3, No. 2 - February 1975	**Short Supply**
Vol. 3, No. 3 - March 1975	**Depleted**
Vol. 3, No. 5 - May 1975	**Available**
Vol. 3, No. 6 - June 1975	**Available**
Vol. 3, No. 7 - July 1975	**Available**
Vol. 3, No. 8 - August 1975	**Available**
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Vol. 3, No. 11 - November 1975	**Available**
Vol. 3, No. 12 - December 1975	**Available**
Vol. 4, No. 1 - January 1976	**Available**
Vol. 4, No. 2 - February 1976	***NYP**
Vol. 4, No. 3 - March 1976	***NYP**
Vol. 4, No. 4 - April 1976	***NYP**
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WANTED — Newspaper clippings on space flights (especially Skylab and Apollo /Soyuz). Write Steve Koenig, 1941 S. Broadmoor Ave., West Covina, CA 91790.

WANTED — Celestron 8 with accessories in mint condition. Contact Robert M. Light, 1409 W. Orchard Ln., Carlsbad, NM 88220. Phone (505) 885-8263.

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WANTED — Correspondence from persons who could build me a 16" to 24" telescope. Please send copies of design and estimates of material and shipping costs. Write Thomas Lucia, 103 Cogswell St., Haverhill, MA 01830.

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INFORMATION WANTED — Plans for 6" reflector or plan that can be suitably adapted. Mount can be either equatorial or altazimuth. Write Kevin Putzer, 1054 W. 10th, Oshkosh, WI 54901.

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INFORMATION WANTED — On construction of huge space or Earthbound telescope using full-period zone plate for the objective. Also resolution of the zone plate on any given wavelength of visible light. Contact David Shipman, 14 LaGoleta Rd., Goleta, CA 93017. Phone (805) 967-5242.

INFORMATION AVAILABLE — Service for "Star Trek". Send questions with SASE to Eric J. Anderson, Star Trek Welcommittee, 906 2nd St. N.W., Ankeny, IA 50021.

ASTRO-NEWS

Latest News From the World of Astronomy

Soviets Plan Search For Intelligent Life

In 1960, American radio astronomer Frank Drake instituted a modest program to eavesdrop on radio emissions from two nearby stars — Epsilon Eridani and Tau Ceti — in an attempt to detect some sign of intelligent life. The program was dubbed Project Ozma, after the legendary queen of Oz.

Ozma produced no results, and was dropped after a few months. Scientists over the years have discussed the possibility of reopening and perhaps expanding the project. But nothing came of it until recently, when the Soviet Academy of Sciences outlined a systematic search of all stars within 100 light-years of the sun — perhaps farther — for radio and infrared radiation that would reveal the presence of intelligent life.

The Soviet Academy proposes two overlapping 15 year plans. As noted recently in **Science News**, the Academy says "efforts to detect extraterrestrial civilizations should proceed smoothly and systematically, and should extend over a prolonged period of time.... It would be a great mistake to build up a program in contemplation of rapid and easy success." This would seem a good starting principle, whether or not one ignores the implied sarcasm toward America's abortive effort.

The Academy points out that such research will be valuable even if it doesn't result in communication with extraterrestrial intelligence. Valuable information about radio emissions from nearby stars would result from the program, which would investigate every star within 100 light-years for signals over the entire shortwave radio astronomy spectrum (from 1 to 100 gigahertz).

It's also possible that a civilization could reveal its presence by infrared radiation. The Russian rocket pioneer Constantine Edwardovitch Tsiolkovski proposed in 1895 that a highly advanced civilization might — after millions of years — totally re-engineer its solar system, using all of its sun's heat and light to support a population billions of times larger than the present population of Earth. The inexorable laws of thermodynamics require that such a solar system sized project must lose heat — heat that we might detect in the form of infrared radiation. The Academy proposes building a special mountaintop infrared observatory just to search for these sources.

The Soviets also suggest a program of continuous monitoring — in radio-wavelengths — of several galaxies external to the Milky Way. Although only a very powerful signal could be detected over such a range, it would allow us to listen to hundreds of billions of stars at once.

Pioneer 11 Yields Saturn Information

For the first time since its history-making Jupiter flyby last year, Pioneer 11 has turned its sophisticated instruments toward a planet — this time the giant ringed world Saturn.

The probe is still too far from Saturn to take useful photographs, but on Nov. 20, 1975 it had come close enough to measure the intensity and polarization of sunlight reflected from the planet's atmosphere and ring system.

The measurements were completely successful. A NASA spokesman said the quality of the data means that we can expect the television pictures of the planet — due in about three years — to be superb.

Pioneer 11 is still over 800 million miles from Saturn, but it sees the ringed planet at a much greater angle (with respect to the sun) than we ever can on Earth. This larger "phase angle" may be the key to new information about the planet's atmosphere and ring system.

Lynn Doose, University of Arizona experimenter in charge of the observations, compares the phase angle effect to an Earthly rainbow.

"On Earth," Doose explains, "if you see sunlight scattered from clouds at a certain angle, you get a sudden brightening known as a rainbow. Planets seen from certain sun angles produce cloudbows. A cloudbow seen on Venus told us there was considerable sulphuric acid in the top of the atmosphere."

Cloudbows seen from Saturn's light at various phase angles will reveal the presence of different gases in the planet's atmosphere. The intensity and polarization of the light may also give us information about the size and distribution of particles that make up Saturn's rings.

First analysis of the observations seems to show about 10 percent less light than scientists had expected. This is, however, within the margin of error they had allowed for this first look.

No firm conclusions will be drawn from the data until more observations are made. Starting in July, a regular series of light measurements will be made.

Star Dies as Nebula Born?

A very small, extremely hot star is being observed either in the act of being born, or in its death throes. Astronomers have been unable to tell whether it is imploding — condensing into a young star — or exploding, which would probably mean it is dying.

The star's position — high above the plane of the Milky Way galaxy, where there is little of the gas and dust necessary for star formation — also makes astronomers think the star is likely to be elderly.

If so, the star is in an evolutionary stage in which a shell of gas and dust is exploded off prior to becoming a white dwarf (the final stage in the life of many stars). Stars with these nebulous shells are called planetary nebulae. In all such nebulae, the gas shells have expanded a great distance from the central star.

This object may be the first star of that class seen at the beginning of its final outburst. Named CRL-618 (after Cambridge Research Laboratory), it is 3,000 to 16,000 light-years from Earth in the constellation Perseus.

CRL-618 consists of a small hot (above 57,000 degrees Fahrenheit) star, invisible because of the dense cloud of gas and dust ejected in the slow explosion. More than 10,000 times the star's diameter, this cloud is what gives off the infrared radiation that was detected by the Air Force's Cambridge Research Laboratory.

The hot central star and its associated gas can be indirectly observed by reflected light from two large dust clouds on either side of the star.

If CRL-618 is indeed a planetary nebula star, then it is one of some 600 such objects that have been catalogued in our galaxy. The best known examples (called "planetary" because they resemble faint planets in a telescope) of these are the Ring nebula and the Dumbbell nebula.

CRL-618 has been observed optically and in the infrared with both the 200 inch telescope at Mount Palomar and the Mount Wilson 100 inch. Infrared observations have been made at Hawaii's Mauna Kea Observatory and radio observations with instruments at Cambridge, England.

The star was discovered by the late William Westbrook, and has been observed by astronomers and students at Caltech, the University of California and Cambridge University.

14th Jovian Moon

The same man who last year discovered Jupiter's 13th moon (see ASTRONOMY, November 1974) has found yet another.

Charles Kowal of Hale Observatories found the satellite on three photographs taken with the 122cm (48 inch) Schmidt camera on Mount Palomar. At 21st magnitude, it is only 1/2,500,000 as bright as Ganymede, Jupiter's largest satellite.

Kitt Peak Scope Used in Daytime

Kitt Peak National Observatory's 158 inch telescope, originally designed for conventional nighttime use, now works a 24 hour day.

Equipped with an ultramodern spectrometer that uses advanced laser and computer technology, the telescope can be used in the daytime to analyze sources of infrared light.

Starlight in the visible spectrum is scattered by Earth's atmosphere, making worthwhile investigation impossible. Infrared light, though, is not so affected.

Scientists will use the 158 inch scope to study dying, late type supergiant stars, hoping for new insights into the final stages of stellar evolution.

Carbon Monoxide Traces in Lower Jovian Atmosphere

Trace amounts of deadly carbon monoxide gas have been found in the lower atmosphere of Jupiter by a joint Jet Propulsion Laboratory-University of Texas team.

The 106 inch telescope at UT's McDonald Observatory provided high resolution spectra in the near infrared region. Carbon monoxide molecules registered on the spectra down to a depth of at least 30 miles — equal to the pressure of about two Earth atmospheres.

Jupiter's atmosphere, which is mostly hydrogen and helium, also contains traces of methane, ammonia, ethane, acetylene, phosphine and water vapor.

Small amounts of carbon monoxide also exist in the atmospheres of Venus, Earth and Mars.

Space Program Backers Testify Before Congress

"Before the end of this century, communications satellites will have decided whether English, Russian, or Chinese is a second language of mankind," speculated Arthur C. Clarke, well-known British science/science fiction writer before the House Subcommittee on Space Science and Applications recently.

Clarke testified along with Norman Cousins, editor of **The Saturday Review**, economist Michael K. Evans, and Edward E. David, former science advisor to the president. Two NASA officials also spoke.

Clarke noted mankind's need to establish "space villages" in permanent Earth orbit (see "Colonies in Space", page 18). He accused space scientists of "failure of nerve", saying that "we often tend to overestimate what we can do in the near future and grossly underestimate what can be done in the more distant future."

Cousins spoke of the philosophical justifications for space travel. Evans argued that increased spending in space research and development could mitigate some of the nation's economic woes. David felt that the federal government should reassess its space funding, allotting at least as much money for basic research as for applications-oriented activities. He said the government "should support exploratory work that has the promise of benefiting society as a whole."

NASA administrator James Fletcher and Donald P. Hearth of Goddard Space Flight Center spoke to the subcommittee, summarizing for them NASA's "Outlook for Space" study.

Some of the congressmen criticized the NASA outlook as being too conservative. "I'd hate to see you guys advising Columbus," said Congressman Louis Frey (R-Fla.).

Other support for space research came from an unusual corner recently. United Nations Secretary-General Kurt Waldheim said in a guest editorial in **Astronautics & Aeronautics** that cosmic research "can open a more productive, safer, and more expansive life for us all." He noted that the sight of Earth from space "evokes the ideal of unity and beauty."

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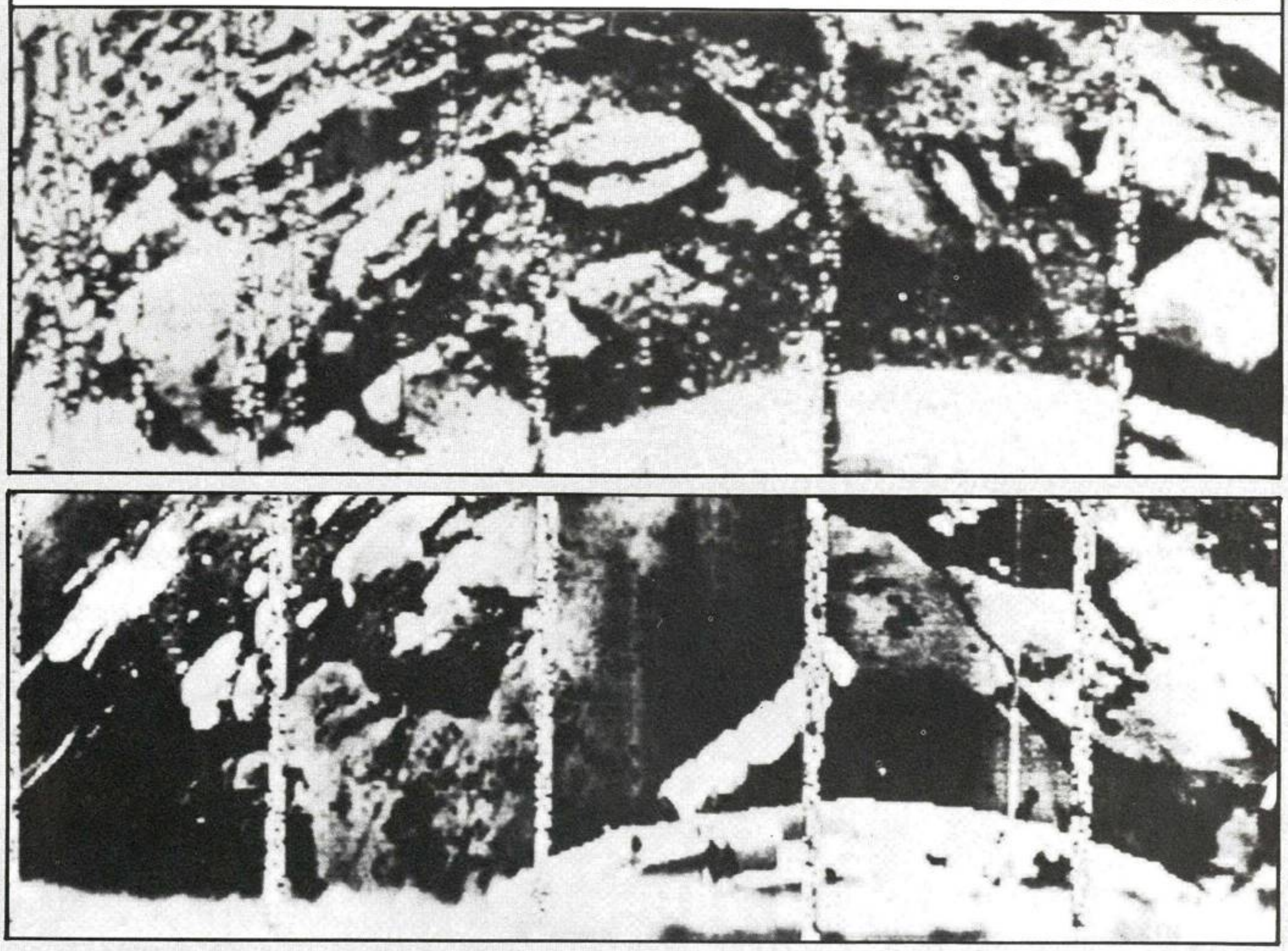
Soviet Probes Reveal Venus Surface



Veneras 9 and 10, landing on Venus on Oct. 22 and 25, 1975, sent back these two surprising photographs of a well lit, still evolving planet. Venera 9 (upper) landed on high ground, some 8,000 feet above "sea" level where the ground was scattered with sharp edged stones. Soviet scientists interpret this as evidence of recent tectonic activity. The rocks photographed by Venera 10, which landed at a lower altitude, do show evidence of weathering. Vertical stripes show interruptions in picture transmission for nonpicture data. The light triangle to far right is a portion of the sky. AP wirephoto (from Tass).

Satellite to Study Cosmic Radiation

The newly formed European Space Agency launched its first satellite — COS-B — on Aug. 8, 1975. COS-B was designed to study extraterrestrial gamma radiation.

The satellite will examine gamma ray flux from both large-scale and small sources, recording intensity and spectrum of the radiation as well as searching for time variations. Long-term variations are expected in certain x-ray sources, and pulsars may show short-period fluctuations (as they do in visible, x-ray and radio wavelengths.

Seven of the ten member countries of ESA participated in the construction of the satellite.

Black Hole in Sun?

There may be a black hole in the center of the sun, according to three Rice University scientists. It could explain the lack of neutrinos in solar radiation.

Conventional theory states that the sun produces light and heat by fusion of hydrogen into helium in the "proton-proton" cycle. The theory predicts a higher rate of neutrino production that has been observed.

Raymond W. Davis Jr. of Brookhaven National Laboratory set up an experiment to measure neutrino radiation by putting a 100,000 gallon tank of cleaning fluid at the bottom of a deep gold mine. Solar neutrinos would then transmute some of the chlorine atoms in the cleaning fluid to argon atoms.

Far less argon was found than had been predicted.

The Rice astrophysicists (Donald Clayton, Michael Newman, and Raymond Talbot Jr.) suggest that the proton-proton theory may be wrong. A very small black hole, embedded in the center of the sun, could produce about half of the star's energy output. Such a star would give off neutrinos at the observed reduced rate.

Matter falling into the black hole would produce the needed energy. As it increased in mass, the black hole would also grow in size. If it has been there since the sun was formed, the black hole may have grown from pinpoint size to several inches in diameter.

This gives us a clue for testing the theory. As the black hole grows, the sun's brilliance should decrease. It may be possible to determine whether Earth (or some other member of the solar system) received more solar radiation in the past than it does now.

Trifid Nebula May Be Clouds Colliding

Radio astronomers investigating the Trifid nebula believe they may be observing two celestial objects in collision. This collision, rather than being destructive, may be giving birth to new stars.

The Trifid nebula in Sagittarius (M-20) is a splendid object when viewed through a telescope. As pictured, it is divided roughly into three (hence the name Trifid) parts by thin, dark lanes of dust.

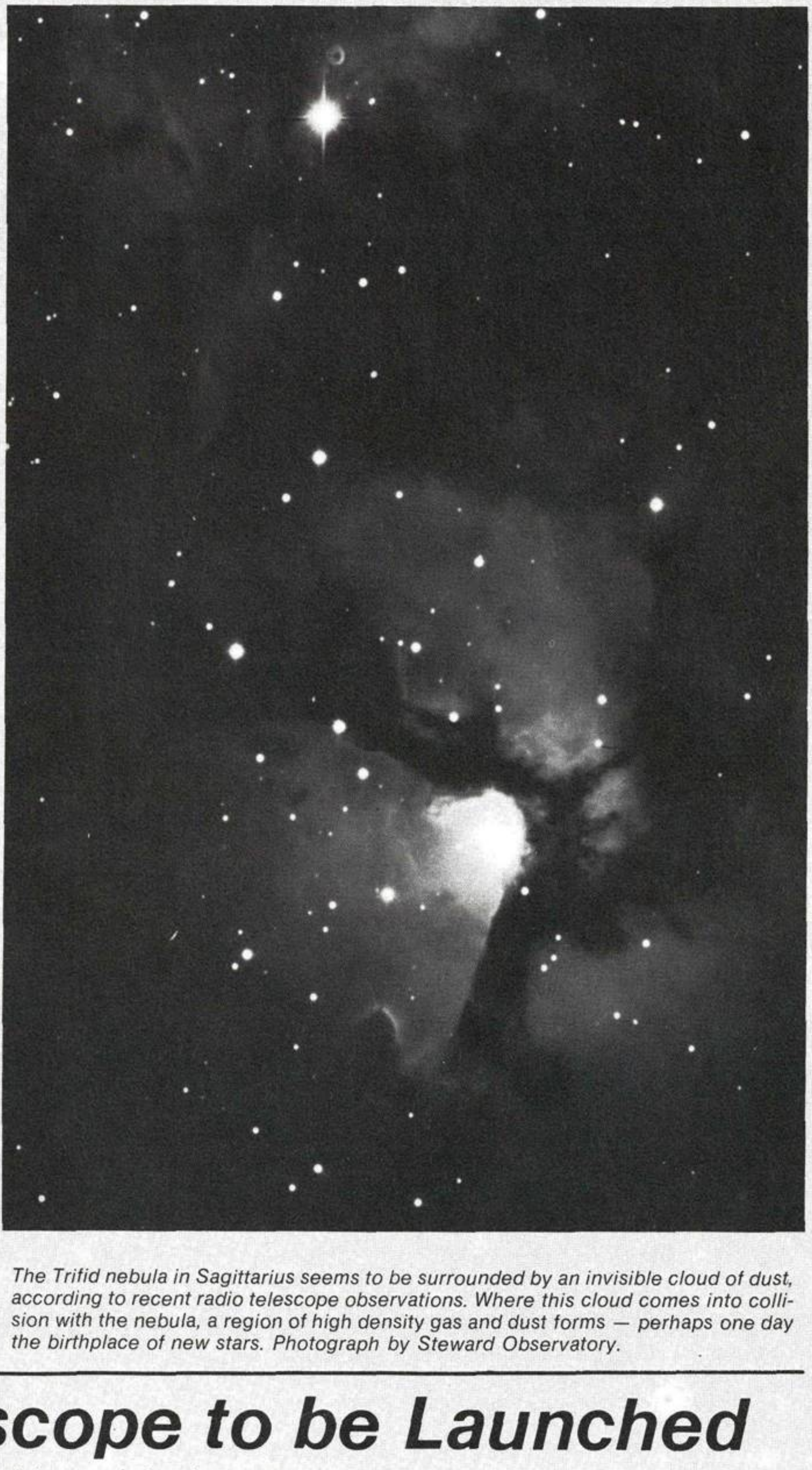
M-20 is a gaseous nebula — a region of ionized gas, mainly hydrogen. A central star gives off the energy that causes the nebula to glow. But recently astronomers have turned their attention to what is not visible — the area surrounding M-20.

Fewer than the normal number of stars are visible in the region around M-20, so scientists inferred that the region was dusty. Inspecting the radio spectra of stars in the area, Eric Chaisson and Robert Willson (Center for Astrophysics, Cambridge) detected two kinds of molecules — hydroxyl and formaldehyde.

This molecular cloud does not actually surround M-20 on all sides. The two objects overlap and may, in fact, be colliding. Where the two masses of matter are merging, they produce a region of higher density, which may give rise to star formation. There's a darker and denser area in the molecular cloud — perhaps the area of collision — which may be undergoing gravitational collapse as a result of the collision-caused increase in density.

This molecular cloud may itself wind up as an object similar to the Trifid nebula. A cloud of interstellar matter seems to evolve from the phase of a quiescent molecular cloud, to a collapsing phase, to (after star formation) a nebula with stars exciting it, to radiate visible light.

If this area shared by the Trifid nebula and the invisible cloud actually is a region of gravitational collapse, the high densities there ought to produce other kinds of molecules, which further radio observation may reveal.



The Trifid nebula in Sagittarius seems to be surrounded by an invisible cloud of dust, according to recent radio telescope observations. Where this cloud comes into collision with the nebula, a region of high density gas and dust forms — perhaps one day the birthplace of new stars. Photograph by Steward Observatory.

X-Ray Telescope to be Launched

An x-ray telescope will take a brief look at the remnants of an exploded star this March in a joint British-American effort.

The telescope will be launched aboard a British Skylark sounding rocket. Attaining an altitude of 72 miles, it will provide the telescope a minimum of 3 minutes 20 seconds observing time before falling back to Earth.

During that time it will observe the distant supernova remnant called Puppis A. The information it collects may shed light on the evolution of stars and perhaps on the formation of neutron stars.

The Skylark project is sponsored by NASA's Office of Space Science. The study is being conducted by Richard B. Hoover of Marshall Space Flight Center, Ian Tuohy of Caltech, and Prof. L. F. Boyd from the University of Birmingham, England.

Astronomical League Sponsors Contest

In conjunction with their annual convention, the Astronomical League is sponsoring a contest for amateur astrophotographers.

Judging will be in four categories: black and white deep sky objects (objects requiring relatively long time exposures and special equipment); black and white general (all other astronomical objects); color deep sky objects; color general.

Awards will be given in each of the four categories after all entries have been judged for astronomical interest and artistic merit.

All entries will be mounted and displayed in a special show at the Kutztown (Penn.) State College gallery. The show will be displayed on a cable television program which has over 150,000 viewers.

The deadline for the contest is July 30, 1976. All entries must be mounted for hanging and can be any size from 5" x 7" to 4' x 8'. Return cover and postage must be provided.

Applications are now available from contest chairman Marion Robson, P.O. Box 105, Parker Ford, PA 19457.

Judges for the contest will be Robert Richardson of Questar Corporation, George Keene of Eastman Kodak Company, and Dr. Evans Kern, dean of art at KSC.

The contest, open only to amateur photographers, may become an annual astronomical league event.

ASTRONOMY hopes to print the winning entries in a special feature in the fall.

Advertise it free in Astro-Mart.

Ice Ages Tied To Galactic Year

Last summer, British and Australian scientists, working independently, presented theories that keyed Earth's ice ages to variations in the sun's brightness, which were somehow related to the *galactic year* (the time it takes the solar system to revolve once around the center of the Milky Way galaxy).

The galactic year is about 303 million years long, and ice ages seem to occur approximately every 150 million years, according to G. E. Williams of Australia.

British astronomer W. H. McCrea proposed that the sun increases in brightness twice each galactic year, as it passes through regions of space that are rich in interstellar dust. The sun's increase in brightness causes an increase in precipitation on Earth, which in turn causes the glaciers to advance.

Experimental evidence supporting this theory comes from Apollo 15 lunar core samples analyzed by two Texas researchers.

John F. Lindsay of the University of Texas and L. F. Srnka of the Lunar Science Institute in Houston searched for recurring layers of dust that might have been deposited on the moon as the solar system passed through these "dust lanes" between the galaxy's spiral arms. They were looking for dust sized particles between 44 and 177 microns (a micron is one millionth of a meter).

The Apollo 15 mission brought back deep core samples from the moon — cylindrical samples punched out of the lunar soil. The researchers looked for cyclic concentrations of proper sized dust in one of these samples.

Since we don't know exactly how rapidly material accumulates on the lunar surface, Lindsay and Srnka couldn't precisely correlate the depth of a dust layer with its age. But they did find three cyclic increases of about the same duration separated by a period of 100 to 200 million years. (See also "Long-Term Forecast Given", Astro-News, September 1975.)

Ariel 5 Observes Extragalactic Nova

Recent satellite observations may have revealed a nova burning in empty space outside our galaxy.

The British x-ray satellite Ariel 5 observed an x-ray nova — a star that increased dramatically in x-ray brightness over a period of days. Named AO620-00, this star became the brightest such source known.

Radio astronomers in Cambridge, England, determined an accurate position for the source by way of radio interferometry. Scientists at Dartmouth searched the area and found a possible optical candidate: a star less than one arc-second away, that recently increased in brightness by seven magnitudes — which means a 600-fold increase in luminosity! Old records show the star underwent a similar outburst in 1917, so the new x-ray source may also be a recurrent nova.

Harvard's William Liller studied Israeli measurements of the star's brightness in various wavelengths, and deduced from its apparent temperature and the effect of interstellar reddening that AO620-00 is some 30 to 50 thousand light-years away. Because the star lies in the opposite direction of our galaxy's center, and our own location is about 10 to 15 thousand light-years from the outer edge of the galaxy, this x-ray nova may be at least 15,000 light-years out into intergalactic space.

Sun a Double Star?

Our sun's family may include a companion star that is too dim and distant to have yet been detected, according to Minnesota astronomer Kris Davidson.

Astrophysical theory allows for the existence of infrared dwarf stars, with masses less than 1/30 the mass of the sun. These stars would be invisible in visual wavelengths, and only faintly visible in the infrared.

Davidson computes that such a star could be orbiting the sun some thousands of astronomical units distant (an astronomical unit is the distance from Earth to the sun — approximately 93,000,000 miles). The smallest possible such star — at around 1/1000 of a solar mass — could be as close as 700 astronomical units. This is about 18 times the distance of Pluto.

At these distances, the star could not be detected by the effect of its feeble gravitational pull.

Davidson believes that such a star might be detectable with present-day infrared astronomy techniques. If one should be found, he proposes the name Lucifer.

Scientists Dismiss Astrology

Strong criticism against the belief that the position of planets at the time of birth can influence a person's life was delivered by Bart J. Bok, past president of the American Astronomical Society, and 185 other leading scientists.

All of them signed a statement, drafted by Bok, that said in part:

"One would imagine, in this day of widespread enlightenment and education, that it would be unnecessary to debunk beliefs based on magic and superstition. Yet, acceptance of astrology pervades modern society. We are especially disturbed by the continued uncritical dissemination of astrological charts, forecasts, and horoscopes by the media and by otherwise reputable newspapers, magazines, and book publishers. This can only contribute to the growth of irrationalism and obscurantism. We believe that the time has come to challenge directly, and forcefully, the pretentious claims of astrological charlatans."

The statement, published in **The Humanist** magazine, was one part of a three-pronged attack on the medieval belief. Two articles in the same journal — by Bok and by Lawrence E. Jerome — investigated the problem in more detail. Bok criticized the "scientific" basis of astrology, while Jerome examined the history of astrology and challenged recent claims by practitioners. According to Jerome, to believe in astrology "is to abandon free will and rationality" in favor of a morally easy acceptance of cosmic predestination.

The statement — signed by such well-known scientific figures as Fred Hoyle, Konrad Lorenz, Linus Pauling, Glenn Seaborg, B.F. Skinner, Harold Urey and Fred Whipple — was not intended to make professional astrologers happy.

"What is needed," said R. Donald Papon, director of the Academy of Mystic Arts, "is more scientists who will open their own scientific biases to allow astrologers to communicate with them." He noted that 83 percent of American daily newspapers carry astrology columns, and six universities offer courses in the subject.

In an interview with **The New York Times**, Bok admitted, "I don't think astronomers can stop astrology, but I think we have a responsibility to speak out every so often to remind the public, especially young people, that this is pure hokum."

Multiple Mirror Telescope Has Unusual Design

A telescope that combines six small mirrors to give the performance of a much larger one has been designed by scientists at the Smithsonian Astrophysical Observatory and the University of Arizona.

In this radical design, six 72 inch mirrors are clustered around a 30 inch guiding telescope, to give the light gathering power of a single telescope of 175 inches diameter.

Radio astronomers have long used "aperture synthesis" telescopes, combining a pair or more of small instruments to approximate the performance of a larger one. But the positions of the instruments have to be measured accurately to within a fraction of the wavelength being studied. Radio waves are on the order of a million times longer than waves of visible light, so the problem of putting together the images from optical mirrors is much more profound.

This multiple mirror telescope will be used for both optical and infrared observations at the Smithsonian's Mt. Hopkins Observatory in Amado, Ariz.

Ultraviolet Flare Stars Common in Galaxy

A class of stars whose brightness in the ultraviolet fluctuates by as large a factor as 100 — in as little as 10 seconds! — is being studied in a joint project involving astronomers from the University of Texas and Brazil.

Only about 30 of these rapidly flashing stars have been studied in any detail, but Dr. David Evans, head of the project at UT, believes they are relatively common objects.

"Since these stars are not very bright, they can only be detected if they are relatively close to us," Evans explains. "Forty to fifty of them are known to exist within 10 parsecs of us — and since that isn't very far in astronomical terms, it can be assumed that they are common components of the galaxy."

The stars are relatively cool, with surface temperatures of 4,000 to 5,000 degrees Fahrenheit. But analysis of the light they emit shows that some parts of their surfaces must be much hotter.

Evans theorizes that the flare stars have large starspots similar to sunspots — cooler areas on the surface that are associated with strong magnetic fields. "Presumably," he says, "the spots are surrounded by hotter material which is heated by radiation disturbances generated by the tremendous magnetic fields...."

These spots seem to cover 10 to 15 percent of the star's surface. They cause the star to fluctuate slowly in brightness as it rotates, with a period of one to five days.

Observations of these flare stars are being made at UT's McDonald Observatory and the observatory at the University of Sao Paulo (Brazil).

NASA Plans Uranus Probe

NASA's Jet Propulsion Laboratory plans to send a Mariner type television probe past the cold giant world Uranus in November 1979. It would be a cosmic billiard shot — similar to the successful Venus-Mercury and Jupiter-Saturn probes — with the probe swinging around Jupiter to slingshot toward Uranus.

Some 85 proposals have been submitted to JPL for experiments to go aboard the spacecraft.

Jim Hyde, technical manager for the project at JPL, says the mission is "go", but its exact status will not be final until NASA's budget receives final approval.

Uranus, 1.78 billion miles from the sun, is the solar system's third largest planet with a diameter of about 30,000 miles. An unusual feature of the planet is that it rolls around in orbit on its side with its polar axis tilted 98 degrees from the plane of the ecliptic. Thus, much of the area surrounding each pole is in total darkness for half of its 84 year orbit. Its atmosphere evidently contains large amounts of methane and ammonia.

The probe is scheduled for launching on Nov. 3, 1979. It will swing by Jupiter on April 10, 1981, and approach Uranus in mid-1985.

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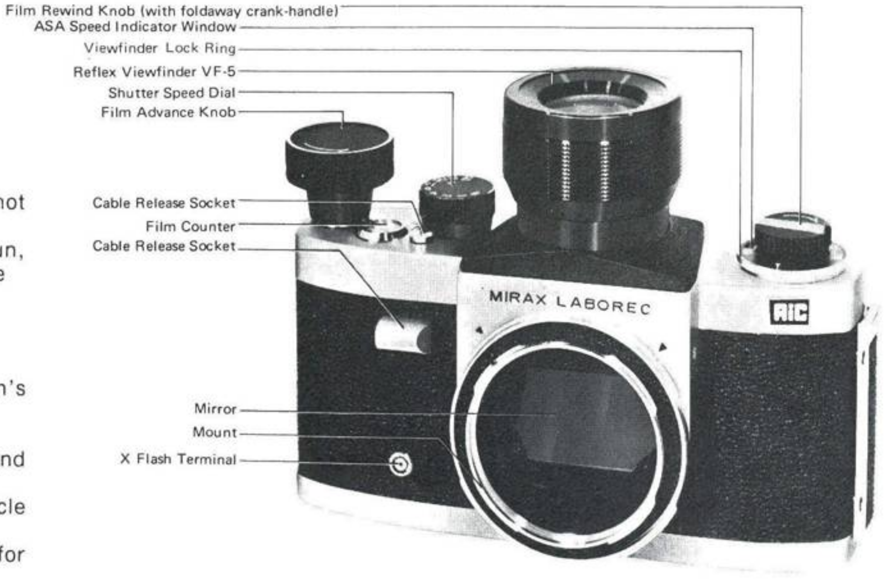
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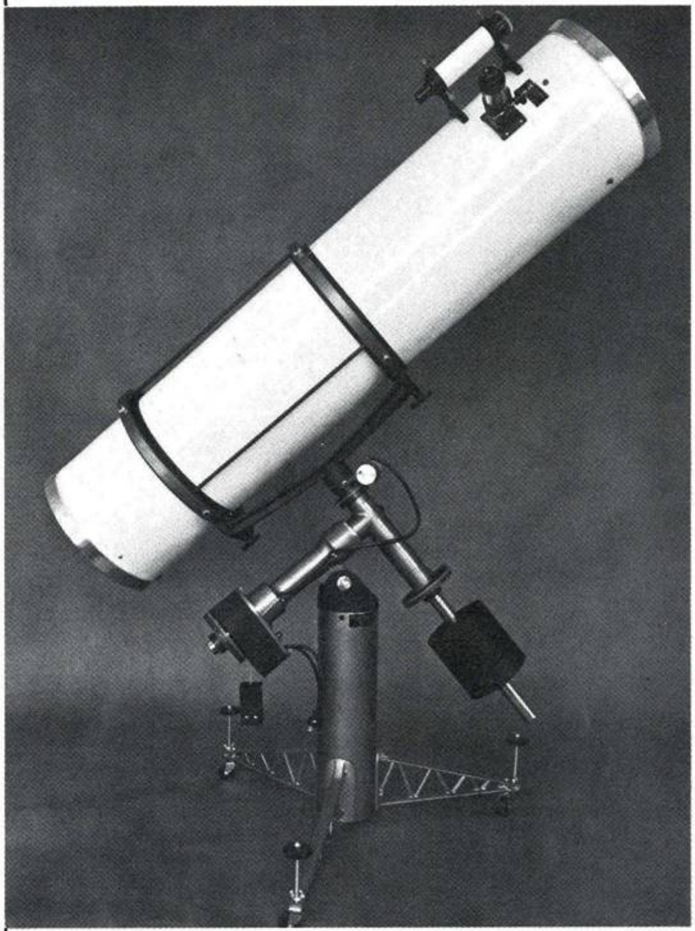

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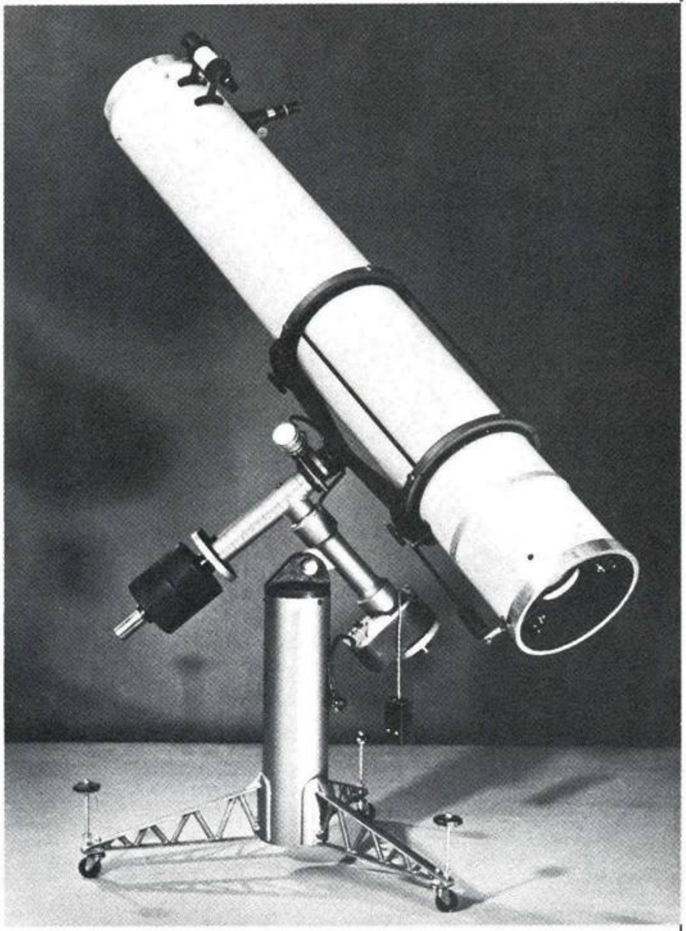

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STAR DOME

JANUARY

by James Mullaney

The great circle of glittering first magnitude stars discussed in Star Dome last month is now approaching the meridian on January evenings. Fomalhaut and the summer triangle have set — with the exception of Deneb which is visible low in the northwest after sunset. Above the western horizon, the Great Square of Pegasus wings its way sunward, while the spring diamond has not yet fully risen in the east.

Against this backdrop of celestial geometry, two additional first magnitude stars have joined our winter sky show. One of these — Regulus in Leo the lion — is rising nearly due east. The other is a star rarely associated with the exclusive "first magnitude club". This is Epsilon Canis Majoris or Adara; at magnitude 1.6, it's the same brightness as Castor in Gemini. Perhaps this object is overshadowed by its brilliant neighbor Sirius.

The winter circle of bright stars provides us with an excellent opportunity to study and compare heavenly hues. In the table below, the magnitudes of these stars are given and their spectral types or classes are compared with their generally reported visual colors.

Star	Mag.	Color	Spectral Type/Class
Capella	0.2	golden orange	G5 + G
Castor	1.6	blue-white	A2 + A0
Pollux	1.2	yellow	K0
Procyon	0.5	yellowish-white	F5
Sirius	-1.4	blue-white	A1
Rigel	0.3	blue-white	B8
Aldebaran	1.1	reddish-orange	K5 + M2
Betelgeuse	0.4-1.3	red	M2

The visual appearance of these stars agrees with the color expected from their spectral type — showing that the tints seen in the night sky are real and not purely subjective in nature. Star color is primarily an indication of temperature rather than composition. Red Betelgeuse, for example, is much cooler than blue-white Rigel, while yellow Procyon lies somewhere between these two in its surface temperature. Thus the human eye — unaided by telescope or complex instrumentation — can actually discern something about the physical state of a remote star!

Close-Up on the Taurus Region

Two outstanding visual attractions of the constellation Taurus are the Pleiades and Hyades star clusters; both are marvelous sights in binoculars and finderscopes. They are, in fact, best seen in such instruments, for telescopes — with their restricted fields of view — can't possibly reveal the full splendor of these groups. The Pleiades were highlighted in last month's Star Dome, and the Hyades are discussed at length in Eyepiece Impressions below.

The ecliptic (pathway of the sun, moon and planets in the sky) arcs through Taurus, passing about midway between the bull's horns — marked by the stars Zeta (ζ) and Beta (β) Tauri. (Beta is an example of a star shared by two adjoining constellations — in this case, Taurus and Auriga.)

Due to the proximity of this celestial highway in the sky, the Pleiades, Hyades and bright Aldebaran are frequently occulted or blocked from view by the moon in its never-ending journey eastward. The seemingly instantaneous disappearance or reappearance of a star as the moon sails silently over it in a kind of cosmic hide-and-seek game is a sight never to be forgotten!

Eyepiece Impressions
Aldebaran

The fiery orange leader of the constellation Taurus was given the name Aldebaran — meaning the hindmost or follower — by Arabian stargazers long ago since it appears to trail the Pleiades across the heavens. This supergiant star of spectral class K is some 37 million miles in diameter, and 100 times more luminous than our own sun.

At its distance of 68 light-years, Aldebaran appears in our skies as a first magnitude star situated against the backdrop of the Hyades star cluster. Its vivid reddish-orange tint is a splendid addition to the colorful array of bright winter stars.

As with celestial hues in general, different eyes may see Aldebaran differently. Admiral Smyth long ago called it pale rose, and some observers have even suspected actual variations with time from yellow to red!

Aside from its lovely warm color, Aldebaran has several faint companion stars in the field with it. According to Webb, "The minute attendant is a good light test... has been seen with a 1-7/8 inch (scope). My 3-7/10 inch (refractor) showed it certainly, but not without much attention; 144 (power) suited it better than 80."

The object Webb referred to is an 11th magnitude orange star about 120 seconds of arc from the primary. Some observers list it as bright as 10th magnitude; nevertheless it is a challenge to see in small telescopes. It appears to be only an optical companion, as it is slowly being left behind due to Aldebaran's motion through space. (The famed double star observer Burnham found this star to be a close pair of 11th and 13th magnitude suns, less than two seconds apart.)

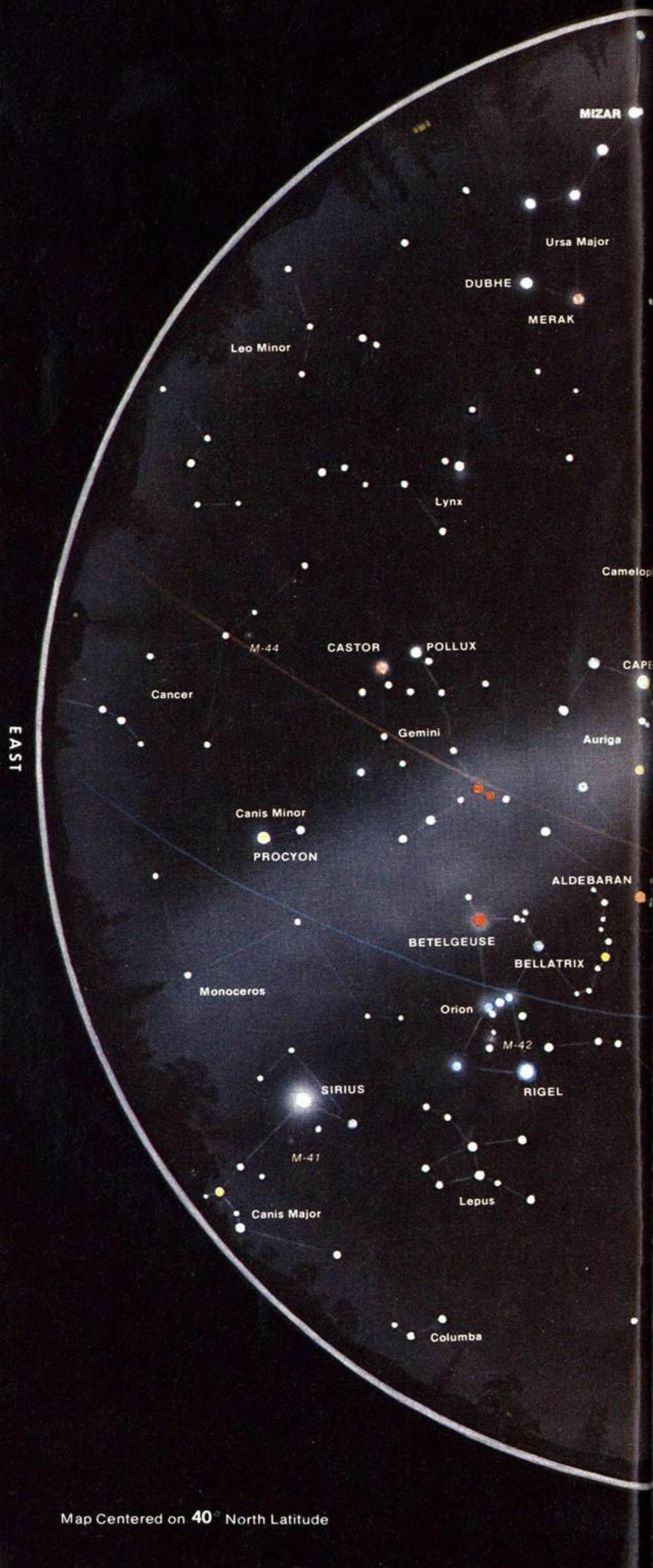
Another somewhat fainter star seems to be traveling with Aldebaran across the sky, forming what is called a common proper motion pair with it. This star has a separation of 31 seconds of arc, and is listed at 11th magnitude.

Although these faint companions make Aldebaran a very poor visual double or triple, they do offer a test of observer, sky and instrument. Glare from the bright primary presents the biggest problem in trying to spot them. Both good seeing and transparent nights are needed for success with small apertures; on such occasions, they are definite in a four inch telescope at 45 power.

Identification of faint or close components of double and multiple stars is much easier if their current position angle — discussed last month — is known. In the case of Aldebaran, the nearer star is at 112 degrees, while the distant one lies near 34 degrees — nearly a quadrant apart.

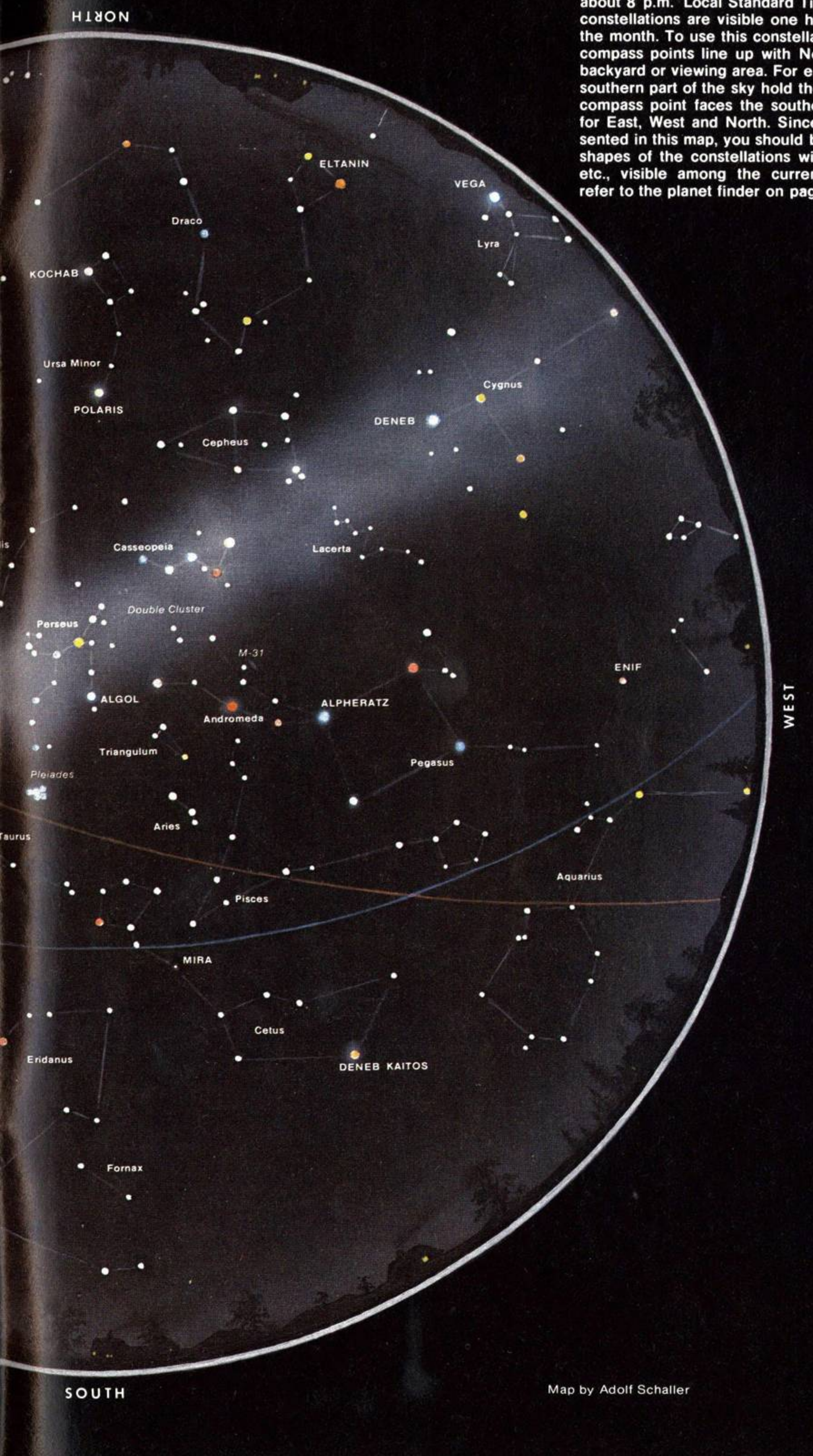
We have previously mentioned the striking appearance taken on by brighter stars as a result of viewing them in good seeing with small apertures (two or three inches) under very high magnifications. Compare the beautiful diffraction disk and rings of Aldebaran in the drawing with that of blue Vega (Star Dome, August 1975).

If you own a telescope larger than three inches, mask down to that size or even smaller — on-axis for a refractor, off-axis for a reflector or catadiop-

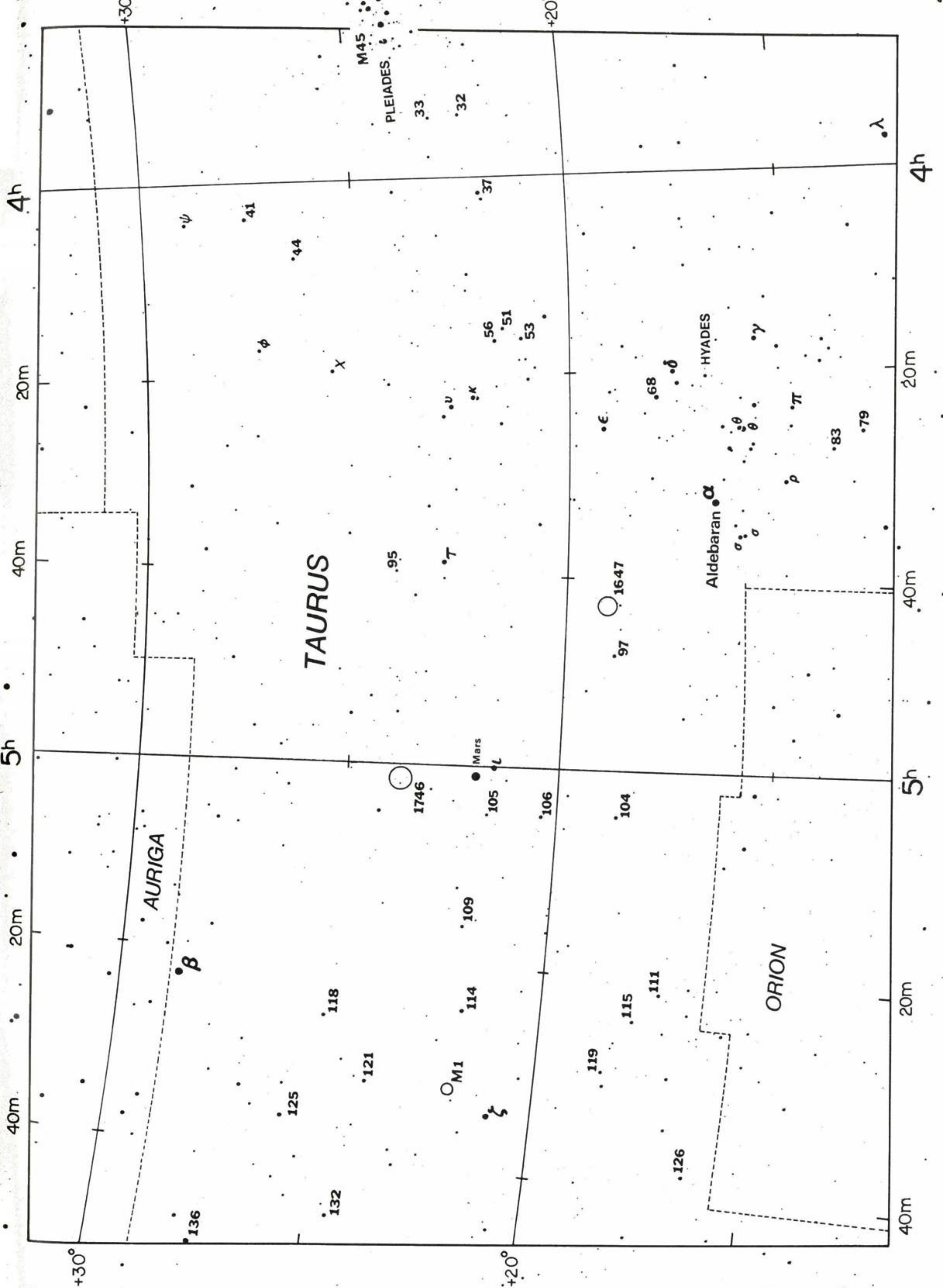


Map Centered on 40° North Latitude

This Star Dome rendering approximates the sky as it appears at about 8 p.m. Local Standard Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder on page 76.


NORTH
ELTANIN
VEGA
Draco
Lyra
KOCHAB
Ursa Minor
Cygnus
POLARIS
DENEB
Cepheus
Casseopeia
Lacerta
Double Cluster
Perseus
M-31
ENIF
ALGOL
ALPHERATZ
Andromeda
WEST
Triangulum
Pegasus
Pleiades
Aries
Taurus
Aquarius
Pisces
MIRA
Cetus
Eridanus
DENEB KAITOS
Fornax
SOUTH

Map by Adolf Schaller


TAURUS
AURIGA
ORION
PLEIADES
M45
HYADES
Aldebaran
Mars
1647
1746
M1
4h
5h
20m
40m
+30°
+20°
α
β
γ
δ
ε
ζ
θ
ι
κ
λ
π
ρ
σ
τ
υ
φ
χ
ψ
32
33
37
41
44
51
53
56
68
79
83
95
97
104
105
106
109
111
114
115
118
119
121
125
126
132
136

Photograph by John Sanford/Map by Victor Costanzo tric due to their central obstructions. Why not try this exciting technique with your own telescope on the next clear evening?

The Hyades

The large V-shaped splash of stars in which Aldebaran appears to be situated presents both a naked eye spectacle and a binocular marvel. This scattered open cluster is known as the Hyades. Most stargazers are disappointed to learn that Aldebaran is not really part of the cluster, but is simply projected against it. At a distance of 130 light-years, the Hyades is one of the nearest such groupings to us — but is almost twice the distance of Aldebaran itself.

Having the combined or integrated brightness of a first magnitude star, the Hyades cluster contains at least 40 suns spread over an area of 330 minutes or 5-1/2 degrees — equal in extent to 11 full moon diameters! Its actual physical size in space is at least 30 light-years, which — combined with its proximity — accounts for its huge angular dimensions.

The members of this celestial commune are all moving together toward the southeast and appear to be converging on a point in the sky near Betelgeuse in Orion. This effect is a result of their actual space motions and perspective (much like a meteor shower in reverse). Note that this is not toward the tip of the "V" [marked by the star Gamma (γ) Tauri], which the cluster's visual appearance would lead us to believe is the convergence point.

Viewed in binoculars, the Hyades is a marvelous sight; the individual stars seem suspended in space against the sky background. Though considered a poor telescopic object by many, the cluster has much of interest to offer users of small telescopes with a low power wide field eyepiece. Barns called this area of the sky "a treasure region, including that blazing V-shaped open cluster — the Hyades — 100 blue-white class A suns, golden solar and red Antarean giants."

"It's Still Greek to Me"

by **Tilman K. Edwards**

Some of the first really good astronomy was performed by Greeks who lived more than 2,000 years ago. Hipparchus, who lived about 100 B.C., mapped the positions of the sun, moon and stars so carefully that later astronomers predicted eclipses by his work. Aristarchus, who lived 100 years earlier than Hipparchus, taught that Earth revolved around the sun. Many of these ideas were lost as the years went by, but even today someone who thinks he has a brand new idea may find that an ancient Greek had it before.

Those of us who are astronomy enthusiasts are reminded of this fact every time we look at a star chart; Greek letters will be there in abundance. Unfortunately, these letters will not follow the same order nor have the same shape as the ones we learned in grade school.

The stars in a constellation are designated by letters in the Greek alphabet in order of decreasing brightness. Therefore it is wise for us to know that the Greek alphabet is Alpha, Beta, Gamma, Delta, etc. (See the sybols table on page 73.) These symbols are not synonymous with the numbers used for magnitude. For example, a star designated Gamma in a constellation may or may not be third magnitude, but it will almost always be the third brightest star in that constellation.

The first six letters (and symbols) of the Greek alphabet used for star brightness descriptions have interesting origins. Alpha (α) comes from the Egyptian hieroglyphic picture symbolizing an ox. Betelgeuse in Orion is Alpha because it is the brightest star in that constellation. In fact, many of the Alpha stars have common names because their brightness has made them especially noticeable. Similarly Aldebaran is Alpha of Taurus the bull; Aldebaran is the ox head (Alpha hieroglyph) in Taurus' head.

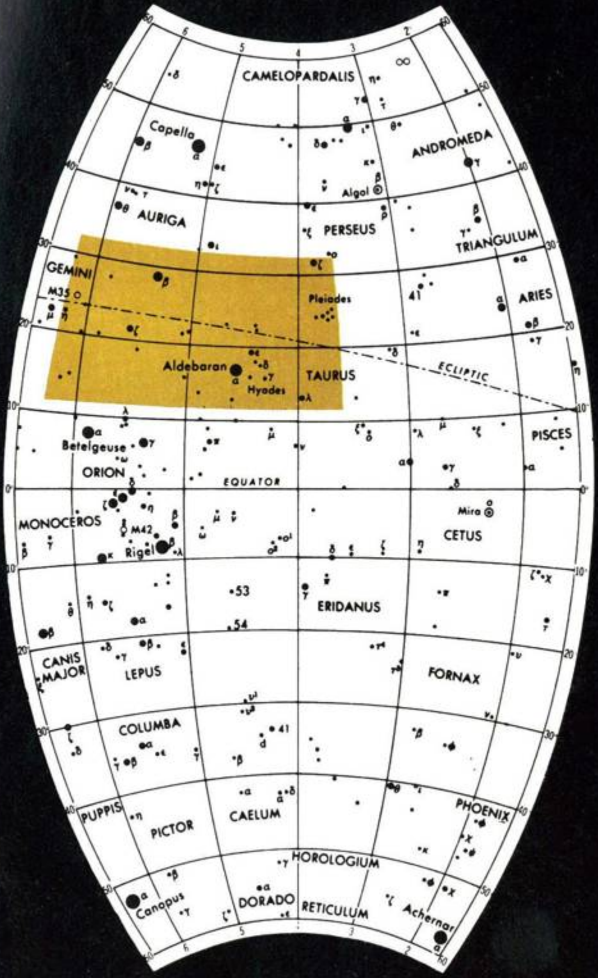
Beta (β) comes from the hieroglyph which signified "house". We might picture a little two gabled house that has been tipped up on its side. The word for house (beth) still lingers in the Hebrew language, and is found in English along with the first letter of the Greek alphabet in our word alpha*bet*. Albireo is the second brightest star in the constellation Cygnus the swan; therefore, it may be termed Beta Cygni. (Cygni is the Latin genative form for English possessive case. It literally translates as Cygnus' Beta or Beta belonging to Cygnus.) Even a small telescope will resolve this third and fifth magnitude double star to reveal a beautiful yellow and blue pair.

Gamma (γ) came from the picture symbol for "boomerang-shaped throwing stick". This symbol on a star chart of the constellation Andromeda designates a lovely double star of second and fifth magnitudes. Gamma Andromedae (there's that genative form again) is the last star in a line that curves northward away from the Great Square of Pegasus.

Delta (δ) is derived from a picture symbol for "door". The Egyptians had a paneled door (◫) which the Phonecians turned into a triangular door (⊿). However, the Greeks balanced this figure as an equilateral triangle (Δ). In the constellation Corvus, Delta signifies the finest double star to be seen in that area of the sky. You can find a picture of Delta Corvi in Eyepiece Impressions (page 74, May 1975).

Epsilon (ϵ) is a "rejoicing man" — a cheerleader who is extending both arms and shouting "Eeeee!" The original figure has been modified as it passed through several languages. One Epsilon star is very easy to find; it is in the constellation Orion — the center of the hunter's three "belt" stars. It is well worth finding, because just below it in Orion's sword is brilliant M-45 — the Great Nebula of Orion.

Zeta (ζ) is derived from a picture symbol for "arrow". Interestingly, the constellation whose symbol is an arrow has a very helpful Zeta star. Sagittarius is filled with fascinating star fields because this constellation is positioned with the center of our Milky Way galaxy behind it. With binoculars, look for diffuse nebulae and both open and globular clusters within its borders. Once you locate Zeta Sagittarii at the bottom of the "teapot" handle, it will be easy to find all the beautiful clusters and nebulae that summer constellations hold.


CAMELOPARDALIS
Capella
AURIGA
PERSEUS
Algol
ANDROMEDA
TRIANGULUM
GEMINI
M35
Pleiades
ARIES
ECLIPTIC
Aldebaran
TAURUS
Hyades
Betelgeuse
ORION
EQUATOR
PISCES
MONOCEROS
M42
Rigel
Mira
CETUS
53
54
ERIDANUS
CANIS MAJOR
LEPUS
FORNAX
COLUMBA
41
PUPPIS
PICTOR
CAELUM
PHOENIX
HOROLOGIUM
Canopus
DORADO
RETICULUM
Achernar

Stars in each constellation are indicated, in order of brightness, with the Greek Alphabet.

α	Alpha	η	Eta	ν	Nu	τ	Tau
β	Beta	θ	Theta	ξ	Xi	υ	Upsilon
γ	Gamma	ι	Iota	ο	Omicron	φ	Phi
δ	Delta	κ	Kappa	π	Pi	χ	Chi
ε	Epsilon	λ	Lambda	ρ	Rho	ψ	Psi
ζ	Zeta	μ	Mu	σ	Sigma	ω	Omega

Map from **Guideposts to the Stars**; reprinted permission of MacMillan Publishing Co., ©1972 by Leslie C. Peltier.

Close-Up on Selected Objects — Taurus Region

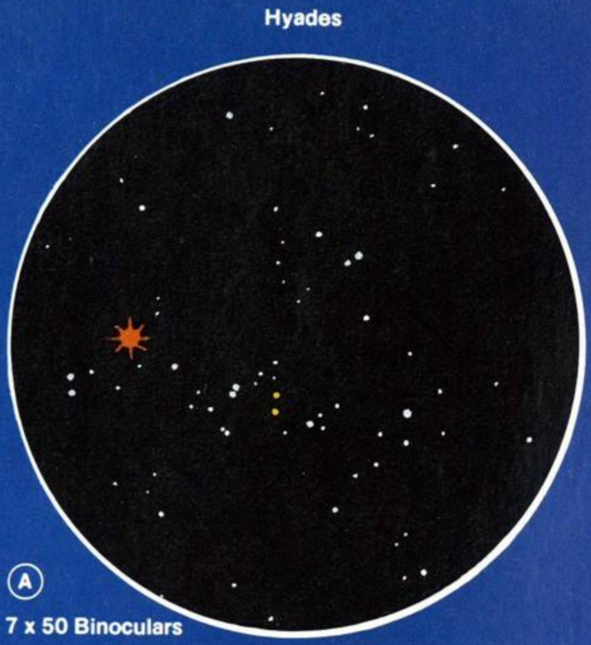
Object	Type	Mag.	Size/Sep.	R.A. (1950)	Dec.
TAURUS					
*Hyades	OC	0.8	5-1/2°	04^h17^m	+15°31'
Burnham 87	✱2	6.1, 9.1	2"	04^h19^m	+20°42'
χChi	✱2	5.4, 8.2	20"	04^h20^m	+25°31'
*θ1-2 (Theta 1&2)	✱2	4.0, 3.6	5-1/2'	04^h26^m	+15°46'
*αAlpha-Aldebaran	✱3	1.1,11,10	31",114"	04^h33^m	+16°25'
*σ1-2 (Sigma 1&2)	✱2	5.2, 4.8	7"	04^h36^m	+15°42'
NGC-1647	OC	6.3	40'	04^h43^m	+18°59'
NGC-1746	OC	6.0	45'	05^h01^m	+23°44'
NGC-1807	OC-2	7.8	10'	05^h08^m	+16°28'
NGC-1817		7.9	15'	05^h09^m	+16°38'
118 Tauri	✱2	5.9, 6.6	5"	05^h26^m	+25°07'
*M-1 (Crab)	PN	8.4	360"x240"	05^h32^m	+21°59'

*Detailed in Eyepiece Impressions

OC=Open Cluster
GC=Globular Cluster
EN=Emission Nebula
RN=Reflection Nebula

PN=Planetary Nebula
El=Elliptical Galaxy
Sp=Spiral Galaxy
Ir=Irregular Galaxy
V=Variable Star

✱2,3,4=Double/Multiple Star
Nr=Nova Star, recurring
Mag.=Magnitude
Sep.=Separation



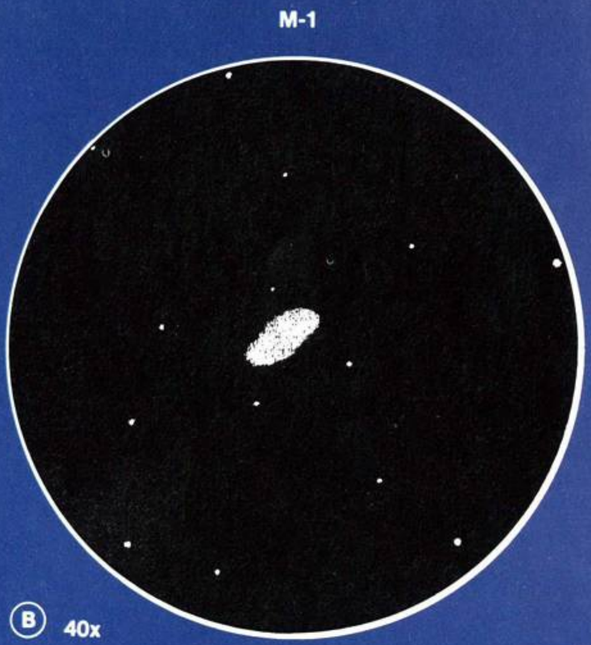
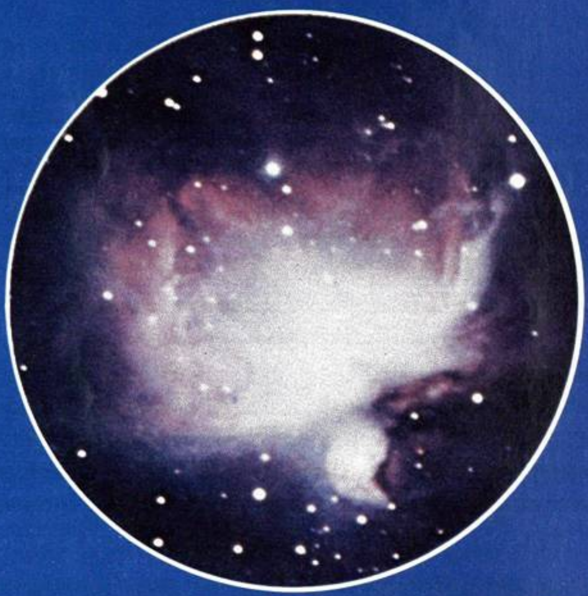
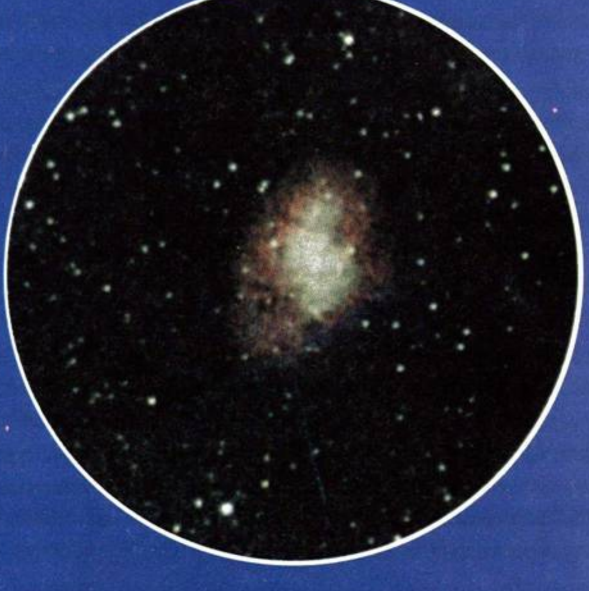


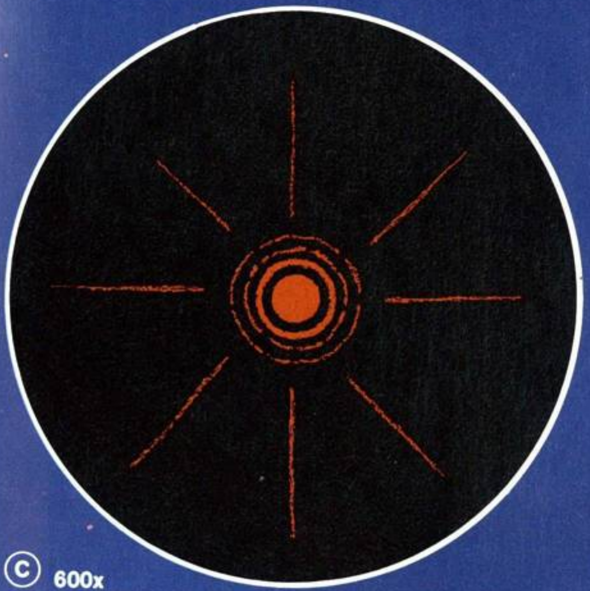
Diagram A shows the Hyades open cluster as it appears in 7 x 50 binoculars. Bright red-orange Aldebaran dominates the field of view, but the dozens of stars in this loose cluster run the gamut from red to blue in color. Diagram B is the way you would see M-1 (the Crab nebula) in a four inch reflector at 40 power with a field of one degree. It would take a much larger telescope to show any of the nebula's complex filimentary structure; in small instruments it appears as an oblong patch of gray, about six by four minutes of arc in extent. Diagram C shows the brilliant diffraction disk of Aldebaran as seen in a three inch refractor at 600 power. Diagrams by James Mullaney.



The Orion nebula (above) is among the most photographed objects in the sky — yet each portrait reveals a different aspect of this immense cloud of interstellar dust and gas. Illuminated by hot stars at its core, the nebula engulfs at least 1,000 cubic light-years. The great cloud is thought to be the birthplace of stars; astronomers believe several hundred brilliant suns will emerge from this stellar incubator during the next several thousand years. Known as M-42, the main nebula is visible to the unaided eye and is a marvelous telescopic sight. Detail seen here is beyond the visual sensitivity of the eye and was made with a six inch f/5 home built Newtonian reflector and GAF film exposed for one hour. At right, planetary nebulae are the puffed-out remains of catastrophic stellar explosions. In a telescope, these tiny nebulae resemble planets — at least in apparent size. As a result, medium and large aperture telescopes and high magnification are necessary to resolve detail. The Crab nebula shown here — a favorite target for beginners — is one of the largest planetary nebulae in the sky. It can be found in the constellation Taurus, just above Zeta Tauri. This photograph was made using a home built 16 inch Newtonian reflector coupled with a home built cold emulsion camera. Above: Photograph by Robert Provin. Right: Photograph by Orien A. Ernest.



Aldebaran



In addition to its glittering array of stellar magnitudes and colors, the Hyades contains many atrractive pairs and combinations of stars. One of the nicest is Theta (θ) 1 and Theta 2 Tauri — a golden duo of fourth magnitude suns some five minutes of arc apart, situated about midway along the bottom of the "V". Another easy pair is Sigma (σ) 1 and Sigma 2 Tauri. These are nearly matched, blue-white, fifth magnitude stars separated by seven minutes and located a degree southeast of Aldebaran.

The separation in both pairs occurs mainly in declination (vertically), and is wide enough to split the stars without optical aid. They make fine binocular objects and offer interesting views in a three inch refractor or four inch reflector at 45 power.

M-1

The line formed by the bottom of the Hyades "V" followed eastward in the sky points to third magnitude Zeta (ζ) Tauri. Exactly one degree northwest of this star is the pale glow of M-1 which can easily be missed during casual sweeping.

Better known as the Crab nebula, this eerie object is the remnant of the famous supernova of 1054. The nebula itself was first noted by Bevis in 1731, and its accidental rediscovery by Messier while following a comet in 1758 led to the compilation of his well-known catalog of clusters and nebulae. His description of M-1 reads, "A whitish light, elongated like the flame of a taper."

At magnitude 8.4, the Crab is visible in binoculars under good sky conditions, and is obvious in a 2.4 inch (60mm) refractor at 30 power. A six inch reflector at 50 power makes its outline and full extent (360 by 240 seconds) definite. The serrated edges and filaments that are evident in photos can be glimpsed in eight inch and larger instruments. Whatever size telescope you use, dark transparent nights and the use of averted (side) vision will be essential to fully appreciate this object.

Webb commented that M-1 is "oblong and pale" and mentions its granular appearance as viewed in his 9.3 inch reflector. As usual, Barns provided a charming note in his log: "Famous 'Crab nebula' of Lord Rosse (the analogy presupposed a strong Irish imagination), fairly defined tho pale." Pickering included M-1 in his 1917 listing of the 60 finest objects in the sky, calling it "a somewhat egg-shaped body".

Lord Rosse named the object from its appearance in his homemade 72 inch metal mirror reflector, and thought it might be resolvable into stars (Webb's granular description?); this was at a time when all nebulae were thought to be composed of unresolved stars. M-1 does indeed look crablike in a 10 or 12 inch reflector on a good night.

Although appearing very much like a typical diffuse nebula in the telescope, the Crab is actually a planetary nebula. Most of these objects show small, bluish-green disks that are quite unlike M-1.

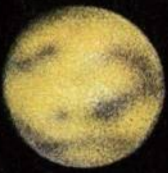
The Crab nebula is composed of incandescent gases expanding outward in all directions at enormous velocities from the site of the original supernova outburst. Viewed from our distance of 6,000 light-years, the explosion actually occurred 60 centuries before it was first seen on Earth (due to the time required for light to reach us). Likewise, we actually are viewing the nebular remains as they appeared that long ago and not their present state. Truly, the telescope is a time machine!

Near the apparent center of the nebula is perhaps the best known and most studied example of a pulsar (a bizarre type of object from the stellar graveyard). Thought to be the neutron star remains of the supernova, it pulsates its light and other energy output at the incredible rate of 30 times per second! So fast is this variation that the human eye and ordinary photographs show the object as constant in brightness! High speed photographic and television image intensification devices clearly show this object blinking on and off.

Photographs of M-1 show a faint double star near the center of the nebula — one component of which is the pulsar itself. Although beyond the reach of small instruments, the well-equipped observer might like to try to view this pair. (For additional information on the nebula and pulsar, see "Why Does the Crab Nebula Shine?", January 1975.)

As we watch the Crab nebula, we are witnessing the death of a star — a star that was perhaps another civilization's sun. Perhaps the grandest thought concerning such events is that inscribed on the crypt containing the intermingled ashes of famed lens maker John Brashear and his wife: "We have loved the stars too fondly to be fearful of the night."

Planet Finder



Ⓒ Ceres

Jan.	1	15
R.A.	4h00m	3h55m
Dec.	+19°10'	+19°50'
Mag.	+6.9	+7.0

Ⓐ Mercury

Jan.	1
R.A.	20h05m
Dec.	-22°04'
Mag.	-0.6

Ⓑ Mercury

Jan.	15
R.A.	20h44m
Dec.	-16°33'
Mag.	+1.4

Ⓜ Mars

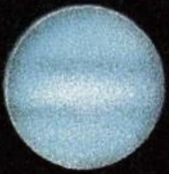
Jan.	1	15
R.A.	5h05m	4h53m
Dec.	+25°58'	+25m42'
Mag.	-1.4	-0.8

Ⓝ Neptune

Jan.	15
R.A.	16h47m
Dec.	-20°52'
Mag.	+7.7

SUN

The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.

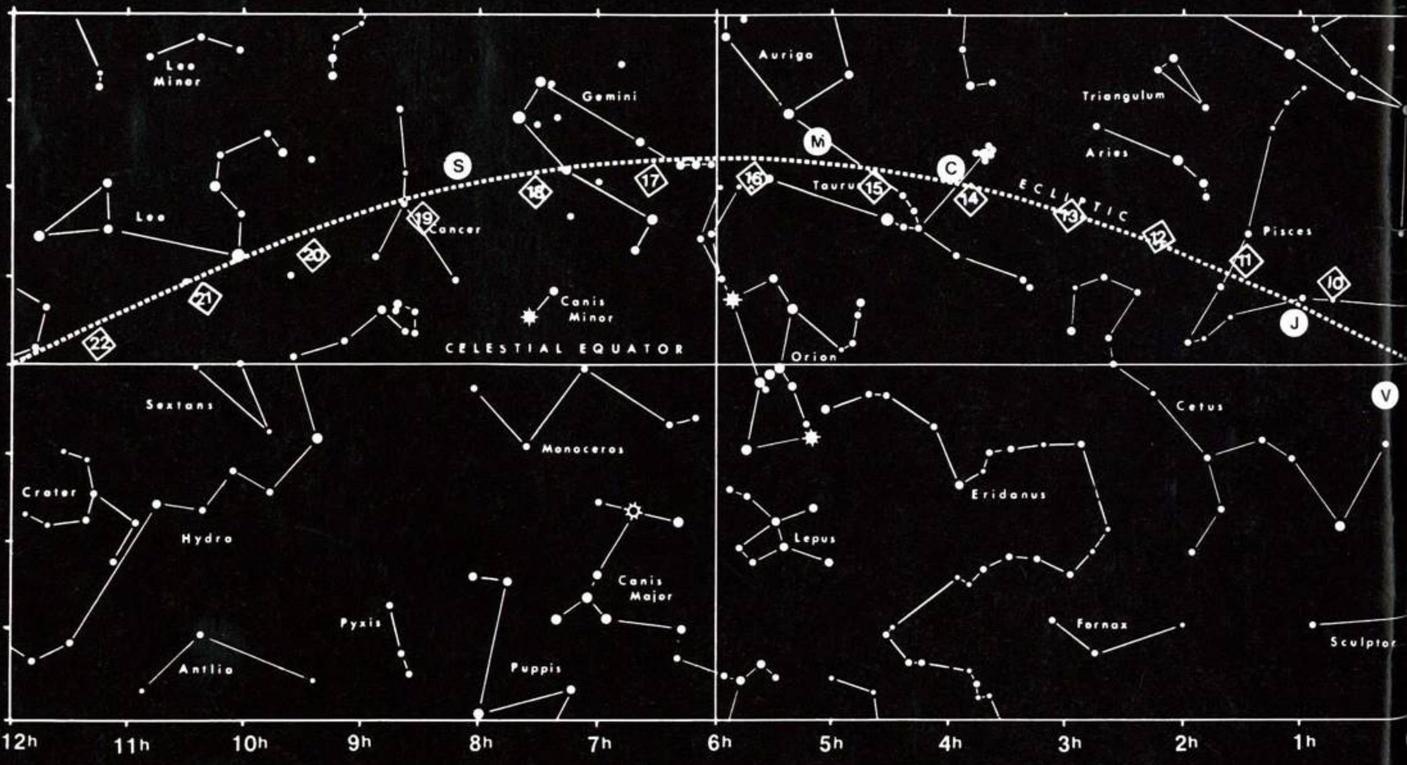


Ⓢ Saturn

Jan.	1	15
R.A.	8h13m	8h08m
Dec.	+20°11'	+20°27'
Mag.	+0.1	-0.1

Ⓤ Uranus

Jan.	15
R.A.	14h18m
Dec.	-13°19'
Mag.	+5.7

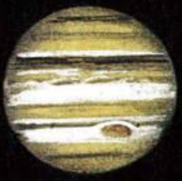

Leo Minor
Gemini
Auriga
Triangulum
Aries
Leo
S
M
C
Taurus
ECLIPTIC
Cancer
Pisces
Canis Minor
CELESTIAL EQUATOR
Orion
J
V
Sextans
Cetus
Monoceros
Crater
Eridanus
Hydra
Lepus
Canis Major
Pyxis
Fornax
Sculptor
Antlia
Puppis
10
11
12
13
14
15
16
17
18
19
20
21
22
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h

The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and Dec . = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. Mag . = magnitude, a

January 1976

Ⓥ Vesta

Jan.	1	15
R.A.	$0^{h}06^{m}$	$0^{h}22^{m}$
Dec.	-7°01'	-4°40'
Mag.	+7.4	+7.6



Ⓙ Jupiter

Jan.	1	15
R.A.	$1^{h}00^{m}$	$1^{h}04^{m}$
Dec.	+4°57'	+5°31'
Mag.	-2.1	-2.0

ⓎVenus

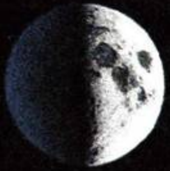
Jan.	1
R.A.	$15^{h}55^{m}$
Dec.	-18°08'
Mag.	-3.6

ⓏVenus

Jan.	15
R.A.	$17^{m}06^{m}$
Dec.	-21°09'
Mag.	-3.5

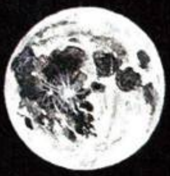
Ⓟ Pluto

Jan.	15
R.A.	$13^{h}08^{m}$
Dec.	+11°10'
Mag.	+14



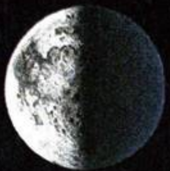
First Quarter

Jan. 9



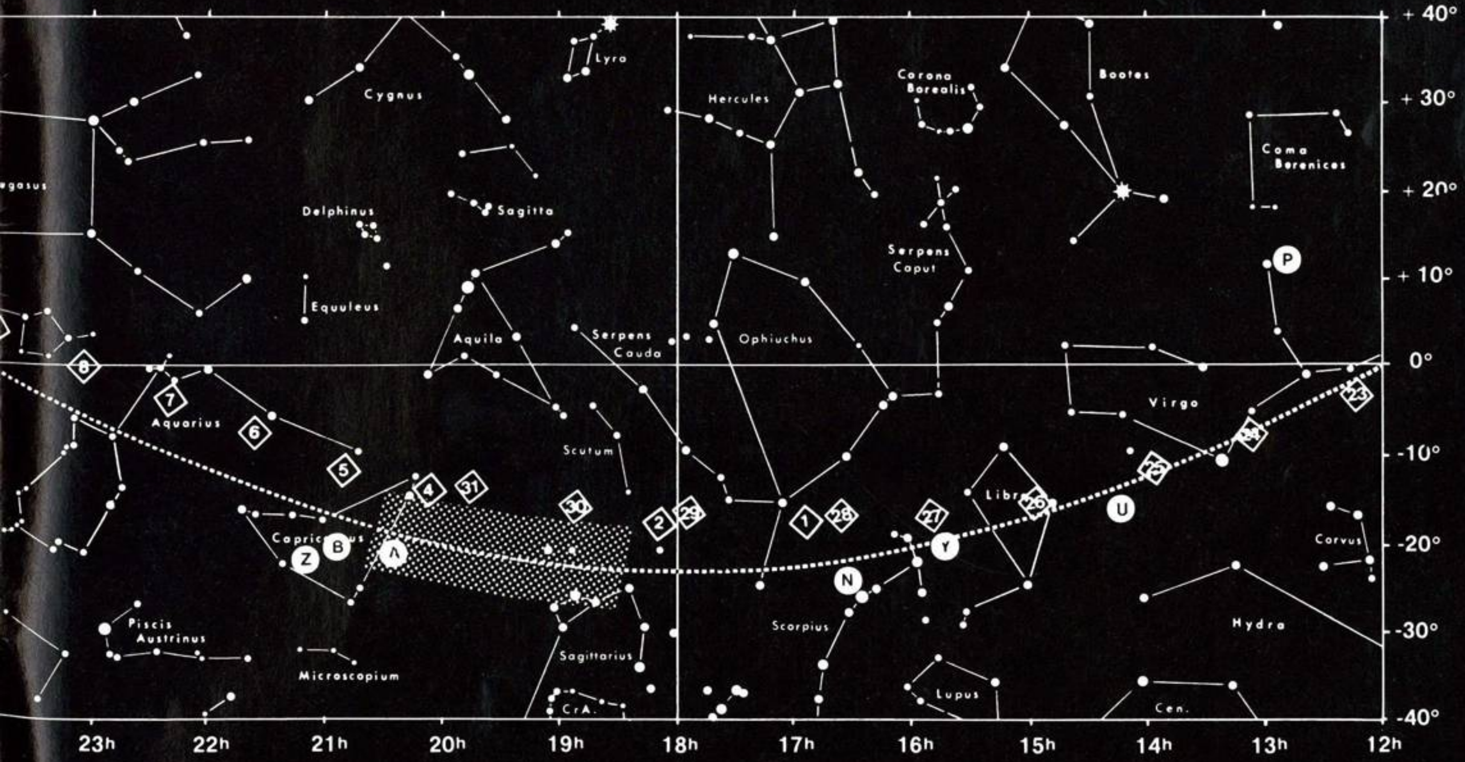
Full Moon

Jan. 17



Last Quarter

Jan. 23


egasus
Cygnus
Lyra
Hercules
Corona Borealis
Bootes
Coma Berenices
Delphinus
Sagitta
Serpens Caput
Equuleus
Aquila
Serpens Cauda
Ophiuchus
Virgo
Aquarius
Scutum
Capricornus
Libra
Corvus
Scorpius
Hydra
Piscis Austrinus
Microscopium
Sagittarius
CrA.
Lupus
Cen.
8
7
6
5
4
31
30
2
29
1
28
27
26
25
24
23
Z
B
A
N
Y
U
P
+40°
+30°
+20°
+10°
0°
-10°
-20°
-30°
-40°
23h
22h
21h
20h
19h
18h
17h
16h
15h
14h
13h
12h

measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th. Certain areas of this map and the Star Dome chart overlap each month.

A
B
C
D
E
F
G
H
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